NEVER DRAIN ENGINE OIL TECHNOLOGY PHASE II

AFLRL REPORT NO. 72

by

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

As the second phase of a program to evaluate methods of extending the life of engine oils, an agreement was reached with Thompson-Ramo-Woolridge, Inc. (TRW) to evaluate an experimental low-blowby piston ring assembly in an L-141 engine. The rings were initially evaluated using an engine dynamometer and were then installed in an M-151 Military Utility Tactical Truck (MUTT) for an extended road evaluation. All tests were conducted using a qualified MIL-L-2104C/MIL-L-46152 grade 30 lubricant and unleaded gasoline meeting VV-G-001690A specifications.

From the results of the 35,400-km (22,000-mile) road evaluation, it appears that these low-blowby piston rings, in conjunction with high-quality level MIL-L-2104C/MIL-L-46152 qualified oils, would allow no-drain

20. ABSTRACT

operation for its 32,000-km (20,000-mile) lifetime of the M-151 vehicle when operated in a high-mileage accumulation, high-temperature mode.

FOREWORD

The work reported herein was conducted at the U.S. Army Fuels and Lubricants Research Laboratory (USAFLRL), located at Southwest Research Institute, San Antonio, Texas, under contract DAAK02-73-C-0221, during the period December 1974 through August 1975. The work was funded by U.S. Army Mobility Equipment Research and Development Command, Ft. Belvoir, Virginia. Project monitor was Mr. T.C. Bowen, USAMERADCOM, DRXFB-GL and contract monitor was Mr. F.W. Schaekel, USAMERADCOM, DRXFB-GL.

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INTRODUCTION

Within the last decade, there has been great concern over the means of disposing of used engine oils from both military and non-military sources. Techniques for recycling the oils or burning them in heating plants have met with continuing problems, particularly those related to the metals content of the used oils. However, a relatively unexplored approach is to extend the life of the lubricants in the engine so that draining becomes unnecessary. For the military, this approach can be particularly attractive in that along with environmental and cost savings, reduction or elimination of engine oil drains has the potential benefits of maintenance savings and increased readiness due to reduced downtime. This approach would also reduce the logistics problems involved with transporting supplies of fresh oils.

Much work done at AFLRL and elsewhere has shown that the primary causes of engine oil degradation are blowby and heat. While little can be done about heat, since the oil is used to help cool the pistons, blowby is the result of imperfect sealing of the combustion chamber. If blowby could be eliminated or substantially reduced, then the engine's oil should degrade more slowly. By increasing or eliminating the oil-drain interval, this would substantially reduce the amount of used oil that must be discarded, and would also potentially reduce the demand for virgin oil.

The first phase of the program[1,2,3,4] * covered the operation of a M-151 Military Utility Tactical Truck (MUTT) under no-oil-drain conditions for 32,180 km (20,000 miles). That road test, over approximately the same course used in this work, indicated that current dual qualified MIL-L-2104C/MIL-L-46152[5,6] lubricants cannot control oil viscosity increases sufficiently to allow no-drain vehicle operation under moderate- to high-temperature operation. However, *except for oil viscosity increase*, the present L-141 engine in the M-151 vehicle, using MIL-L-2104C/MIL-L-46152 qualified lubricants, showed the potential for extended drain operation without formation of excessive deposits or wear.

This report, which covers the second phase of an ongoing program to define methods of extending the life of engine oils by mechanical modifications to the engine, deals with an experimental piston ring configuration intended to substantially reduce the amount of blowby.

EXPERIMENTAL EQUIPMENT

Thompson-Ramo-Woodridge, Inc. (TRW) provided four sets of a low-blowby piston ring configuration for the L-141 engine under a cooperative agreement with the U.S. Army Fuels and Lubricants Research Laboratory (AFLRL). This piston ring configuration (Figure 1) consists of conventional top and oil control rings plus two narrow rings and an elastomer seal in place of the normal second ring. The two rings, both tapered face type, are installed with their ring

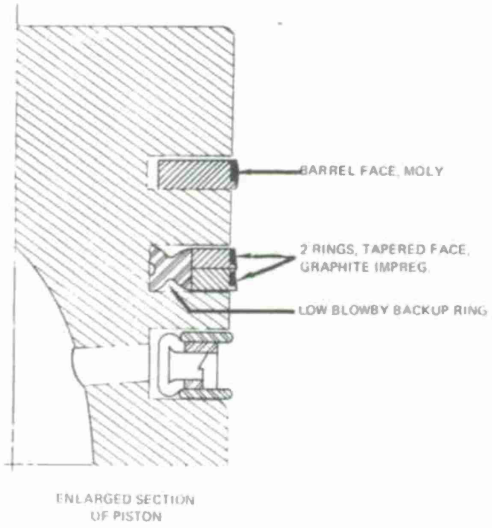


FIGURE 1. TRW LOW-BLOWBY PISTON RING CONFIGURATION

*Superscript numbers in parentheses indicate references at the end of this report.

gaps 180 deg apart to seal the ring gap opening, and the elastomer seal, of semi-cloverleaf cross section, seals the blowby path around the back of the rings and also keeps them from rotating. The only piston modification required was slight widening and deepening of the second ring groove. Since the rings were molybdenum faced rather than the chrome and cast iron rings of the standard engine, the cylinder bore surface finish was smoothed to the 5- to 15-μin. range, compared with the 15- to 40-μin. range for the standard engine.

New L-141 engines, used in the M-151 Military Utility Tactical Truck (MUTT), were provided by TACOM, as were two complete M-151 vehicles which were used for the road evaluation phase of both this and the previous work.

For the laboratory phase of this work, an engine was installed on a 130-kW (175-hp) eddy current dynamometer with provisions for speed and load control. Engine speed was measured using a 60-tooth gear, magnetic pickup and digital frequency counter while load was measured by cradling the dynamometer and measuring its torque reaction with a BLH strain gauge-type load cell and digital indicator. The engine's fuel consumption was measured by a Flotron mass flowmeter capable of determining fuel flow rate to within 0.05 kg/hr (0.1 lb/hr). Engine blowby was measured by first removing the existing positive crankcase ventilation system and providing a vent in the crankcase that could be connected to a flowmeter. The blowby gases were routed through a jacket water-heated heat exchanger to keep the blowby gases from cooling below the dew point. The gases were then measured with a calibrated dry gas meter before being exhausted into the test cell. All blowby flow rates were corrected to 55°C (120°F).

REO-203, a qualified MIL-L-2104C/MIL-L-46152 grade 30 lubricant, was used throughout both the dynamometer and road evaluations. Physical inspection data from this oil are given in Appendix A. For the dynamometer portion, a VV-G-001690A[8] unleaded gasoline (coded AL-5473) was used, while during the road test phase a commercial product meeting VV-G-001690A specifications was utilized. Physical inspections and specification comparisons of the two fuels are given in Appendix B.

During the road test portion of this work, the modified engine was equipped with all standard components other than the special piston rings and was tuned to standard specifications.

TEST PROCEDURES

Dynamometer Evaluations

A dynamometer cycle based on road load measurements from the M-151 vehicles was used to evaluate differences in oil degradation rate with the low-blowby rings. This test cycle, Appendix C, simulated an 80-km/hr (50-mile/hr) road load period, a 56-km/hr (35-mile/hr) high-load period, and an idle period. A 100-hr period of operation with this cycle would thus represent 5430 km (3375) miles) traveled. Three tests were conducted in this manner, a 150-hr evaluation with the standard rings, and two 225-hr tests, one with low-blowby rings and the other with standard rings. Engine oil consumption was measured every 7.5 hr and oil samples taken every 15 hr.

Oil consumption was measured by draining the oil into a weighed container for a fixed length of time (5 min) during the same period in the test cycle. The weight of oil consumed was then determined and an equal amount of new oil added. The oil was then returned to the engine. Samples of used oil were taken prior to the fresh oil additions. At the end of each test, the engine was disassembled and measured for wear and rated for engine deposits. Since there is no

standardized rating method for field-operated spark ignition engines and the established spark ignition engine deposit rating practices (i.e., CRC Manual 9) have been found to be inadequate, the piston carbon and varnish deposits on both the laboratory and field test engines were rated in accordance with standard CRC diesel engine deposit rating methods. Complete test results are given in Appendix D.

Road Test

After completion of the laboratory engine tests, two new L-141 engines were prepared for installation in M-151 vehicles by first disassembling and measuring the engines, then installing a low-blowby ring set in one engine. The two vehicles, which were loaded to their rated cross country capacity of 249 kg (550 lb), were operated over a 45.5-km (28.3-mile) course consisting of 34 percent unimproved roads and 18 percent highway speeds on level roads. The remainder was low-speed post-type operation. The two vehicles were driven 16 hr per day, 5 days per week and accumulated mileage at approximately 650 km (400 miles) per day. A summary of the operating conditions is given in Appendix F. Both vehicles were operated on unleaded gasoline (code AL-5894) meeting VV-G-001690A specifications.

Engine oil samples were taken every 4800 km (3000 miles), and the engines were tuned and road octane determinations made every 12,900 km (8000 miles). This was continued for the 35,700-km (22,200-mile) duration of the test.

DISCUSSION OF RESULTS

Dynamometer Evaluation

Initial full-throttle performance evaluations of the low-blowby rings (Figures 2 and 3) showed as much as a 65-percent reduction in blowby without a power- or fuel-consumption penalty. Although the low-blowby piston rings cause an additional line of bore contact, either the resultant friction is insignificant or the ring face coatings reduce friction from ring drag to approximately the level of the standard engine.

Three extended duration tests were then conducted, and detailed test results are given in Appendix D, while Table 1 summarizes the operating conditions for the tests. All three tests were completed without incident or unscheduled shutdowns. While power and specific fuel consumption were similar with the low-blowby rings, blowby at the loaded conditions was reduced as much as 80 percent, and the oil sump temperature was reduced 5 deg Celcius (9 deg F). Used oil analysis showed no significant differences in degradation rates except for a departure in acid and base number (Figure 4) for the standard ring-equipped engine's oil compared with that of the low-blowby ring-equipped engine after approximately 125 hr. The base number of the standard engine's oil decreased by 57 percent to 2.2 after 225 hr while in the same period the modified engine's oil had only a 6-percent decrease. This degradation was also observed in total acid number where the standard engine's oil increased 83 percent while the modified engine increased 33 percent.

There were no significant differences between the two ring systems in the rate of change in engine oil viscosity. By 195 test hours, both oils had increased by 23 percent to approximately 150 cSt at 38°C (100°F). While there was some difference in final oil viscosities between the two 225-hr tests, these appeared during the last 30 hr of the test, and further testing would be required to determine if these differences were significant.

TABLE 1. AVERAGE OPERATING CONDITIONS, DYNAMOMETER EVALUATION

Test No.	1	2	3
Piston Ring Type	Standard	Low Blowby	Standard
Hours Completed	150	225	225
Total Oil Consumed, kg (lb)	0.736 (1.62)	1.76 (3.87)	2.04 (4.49)
2800 RPM Mode			
Torque, N-m (lb/ft)	127 (94)	126 (93)	125 (92)
Observed Power, kW (bHp)	37.5 (50.3)	37.1 (49.7)	36.7 (49.2)
Specific Fuel Consumption, kg/kW-hr (lb/bHp-hr)	0.331 (0.544)	0.330 (0.542)	0.317 (0.521)
Blowby at 49°C, m^3/hr (ft^3/hr)	1.35 (47.8)	0.27 (9.7)	1.29 (45.6)
Sump Temperature, °C (°F)	121 (250)	116 (241)	122 (251)
2000 RPM Mode			
Torque, N-m (lb/ft)	129 (95)	129 (95)	127 (94)
Observed Power, kW (bHp)	26.9 (36.1)	27.1 (36.3)	26.6 (35.7)
Specific Fuel Consumption kg/kW-hr (lb/bHp-hr)	0.352 (0.579)	0.344 (0.566)	0.332 (0.546)
Blowby at 49°C, m^3/hr (ft^3/hr)	1.00 (35.3)	0.25 (8.7)	0.909 (32.1)
Sump Temperature, °C (°F)	102 (216)	97 (207)	104 (220)
Idle Mode			
Torque, N-m (lb/ft)	0	0	0
Observed Power, kW (bHp)	0	0	0
Blowby at 49°C, m^3/hr (ft^3/hr)	0.249 (8.8)	0.062 (2.2)	0
Sump Temperature, °C (°F)	62 (144)	59 (139)	59 (138)

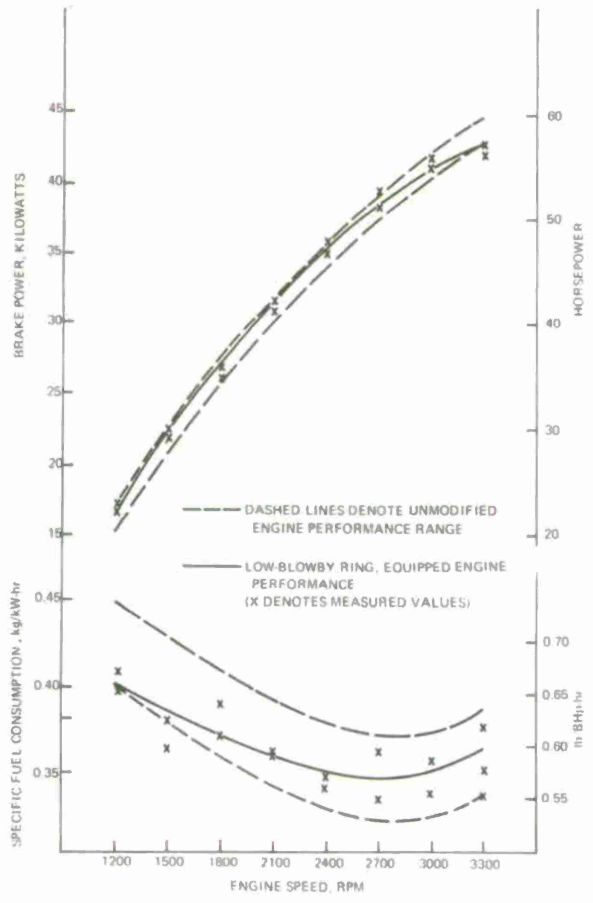


FIGURE 2. FULL THROTTLE POWER AND SPECIFIC FUEL CONSUMPTION L-141 ENGINE

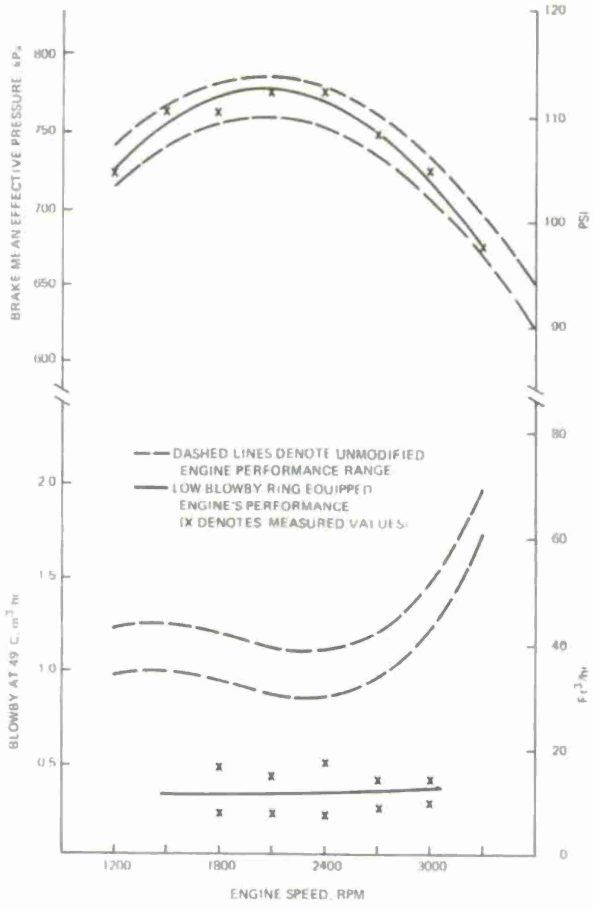


FIGURE 3. FULL THROTTLE MEAN EFFECTIVE PRESSURE AND BLOWBY L-141 ENGINE

Ring wear as evidenced by changes in end gap was negligible, and there were no signs of distress nor was there any evidence of deterioration of the elastomer seal. Deposits were light, with the piston deposits for the two 225-hr tests falling in the range of 10 to 20 when rated using the AFLRL modified deposit rating method, which assigns a demerit rating ranging from a clean of 0 to as much as 700 conceivable for a totally carbon-encrusted piston. Detailed oil analysis data and deposit and wear measurements are given in Appendix D.

Road Test

When the dynamometer evaluations were completed, a road test of the low-blowby ring package was conducted using two M-151 vehicles, one of which was to provide a standard for comparison. Both vehicles were operated without changing either the engine oil or oil filter and adding oil only when necessary. The road test route is summarized in Appendix E, and detailed results of the test are given in Appendix F.

While both vehicles completed the test without engine-related problems, there were significant differences between the two vehicles, with the viscosities of the engine oils being the limiting factor in no-drain operation.

Figures 5 and 6 show the oil viscosities throughout the test. Note that the end of test oil viscosity from the unmodified engine had increased from 12.61 cSt at 99°C (210°F) to 20.34 cSt at 99°C, a 61-percent increase that put the oil well into the SAE 50 grade range. The oil viscosity in the modified engine was in the SAE 40 grade range with 16.59 cSt at 99°C (210°F), an increase of 32 percent from the new oil. The oil viscosity at 38°C (100°F), often more sensitive to oil thickening, had increased 103 percent to 246.8 cSt in the standard engine and by 55 percent to 187.0 cSt in the modified engine. These viscosity increases, particularly that in the unmodified engine, were considered unacceptable.

Figure 7 shows the cumulative oil consumption for the two vehicles. The consumption rates, 11,400 km/liter (6700 miles/quart) for the

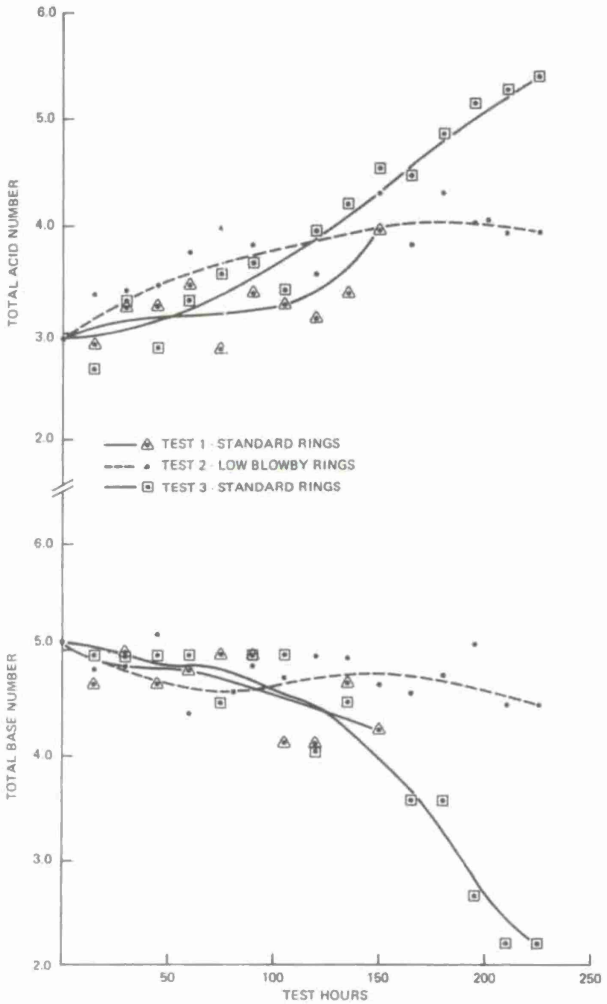


FIGURE 4. CHANGE IN TAN AND TBN DYNAMOMETER EVALUATION

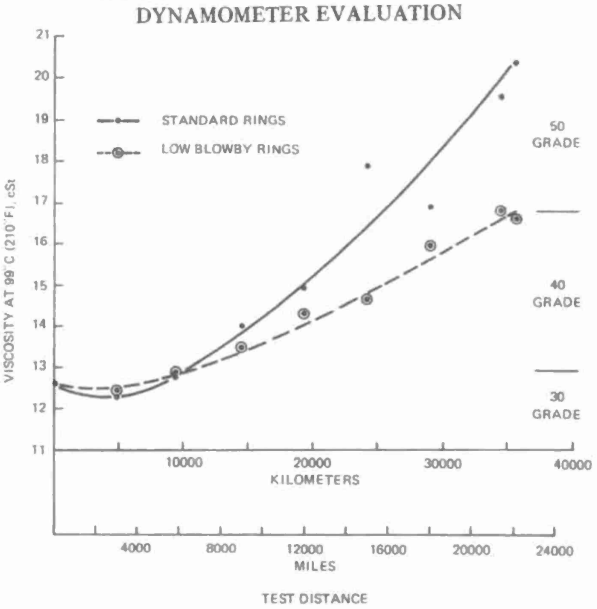


FIGURE 5. ENGINE OIL VISCOSITY AT 99°C M-151 ROAD TEST

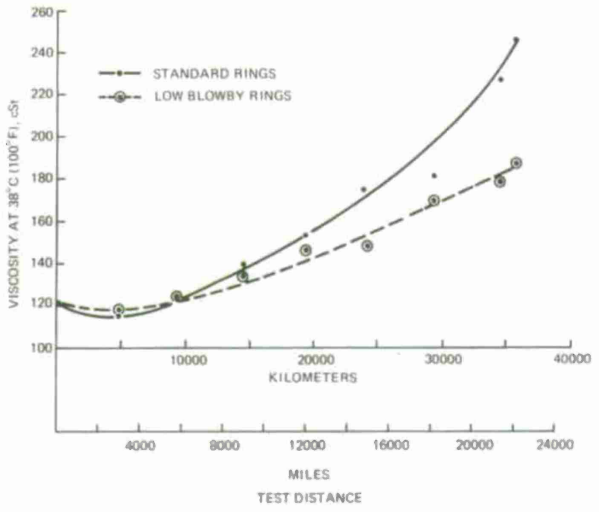


FIGURE 6. ENGINE OIL VISCOSITY AT 38°C
M-151 ROAD TEST

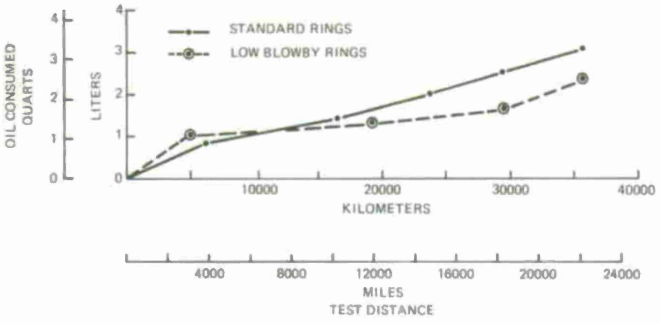


FIGURE 7. CUMULATIVE OIL CONSUMPTION
M-151 ROAD TEST

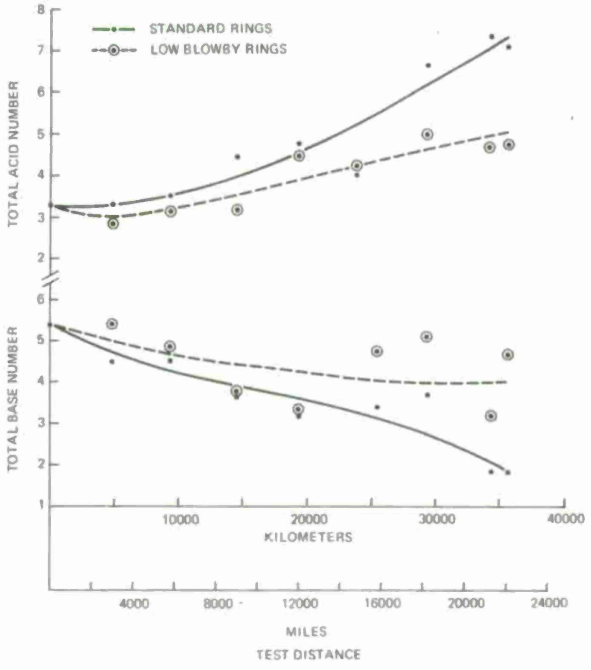


FIGURE 8. ACID AND BASE NUMBER CHANGES
M-151 ROAD TEST

standard engine and 15,000 km/liter (8800 miles/quart) for the modified engine, were considered unusually low, and this lack of oil consumption and subsequent low oil addition rate contributed to the increased oil degradation. Earlier M-151 vehicle operation over this course[1] had averaged 10,000 km/liter (5800 miles/quart) and other studies[9] had shown consumption rates for this vehicle averaging as high as 560 km/liter (330 miles/quart).

Figure 8 shows the total acid number and total base number changes for the two engine oils. The more rapid increase in TAN with an associated TBN decrease indicates a more rapid oil additive depletion rate in the standard engine. Differential infrared analysis of the final oil drains, Figure 9, substantiate this by the larger increase in oxidation and nitration products in the oil of the unmodified engine. The oxidation products absorption peak at 1720 cm^{-1} indicate approximately three times greater concentration of oxidation products in the standard engine's oil than in the modified engine's. There appears to be eight times as much nitration in the standard engine as in the modified engine, based on the nitrogen compound absorption peak at 1640 cm^{-1}. This is substantiated by other nitrogen compound absorption peaks throughout the spectrum, particularly that at 860 cm^{-1}. This picture of reduced oil degradation in the low-blowby ring equipped engine is again shown in the pentane and benzene insolubles content of the final oil drain. The arithmetic difference between procedure B pentane and benzene insolubles, Figure 10, which indicates the amount of insoluble resins in the oil, was three times higher in the standard engine than in the modified engine. These oil analysis data indicate that the low-blowby piston rings reduced oil degradation due to oxidation and nitration by at least a factor of two. The viscosity increases of the oils showed this engine severity reduction, but it appears that this reduction is not adequate to continually maintain

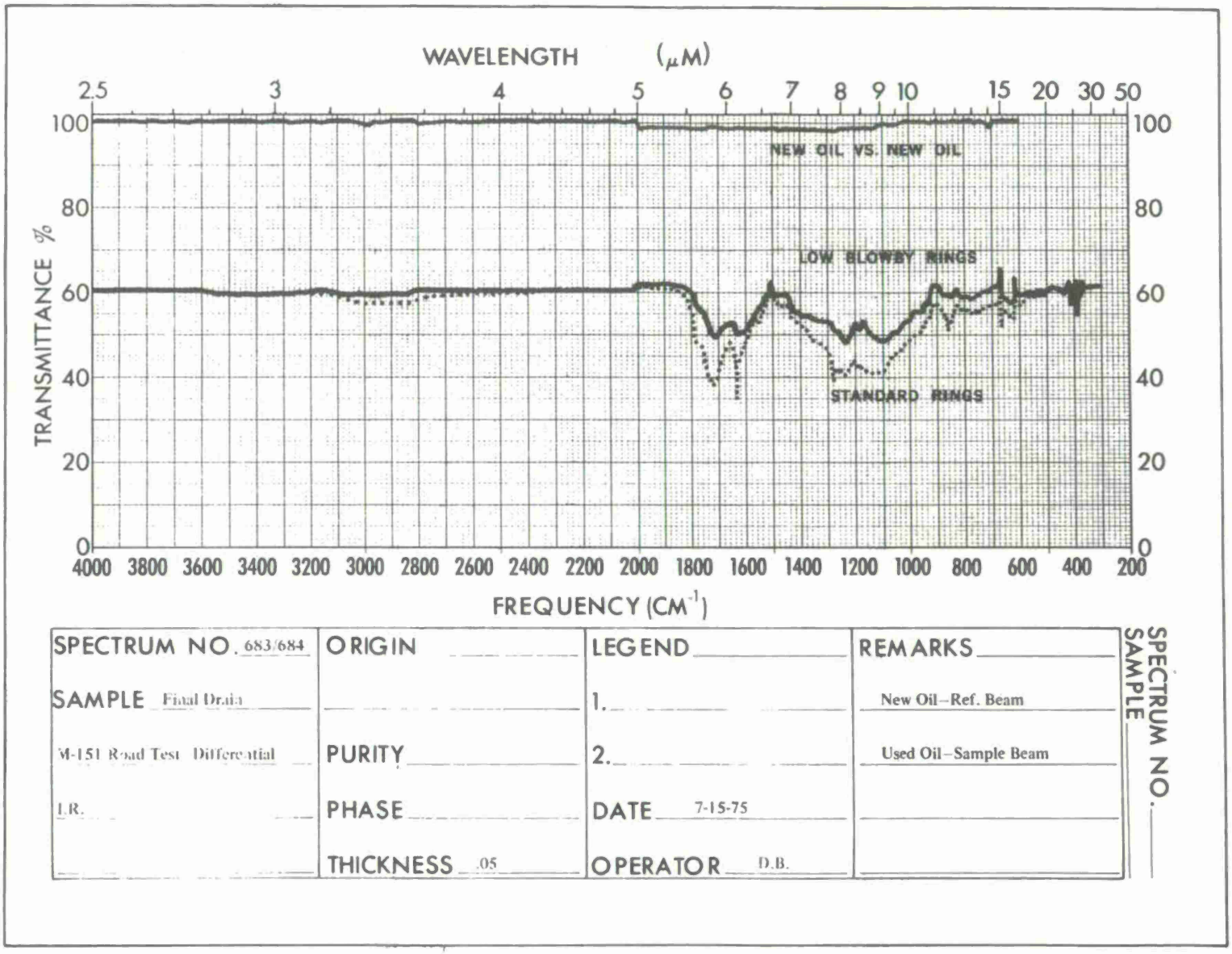


FIGURE 9. DIFFERENTIAL INFRARED ANALYSIS OF FINAL OIL SAMPLES, M-151 ROAD TEST

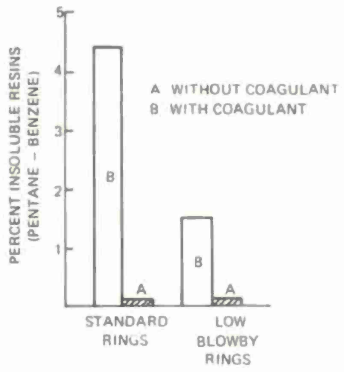
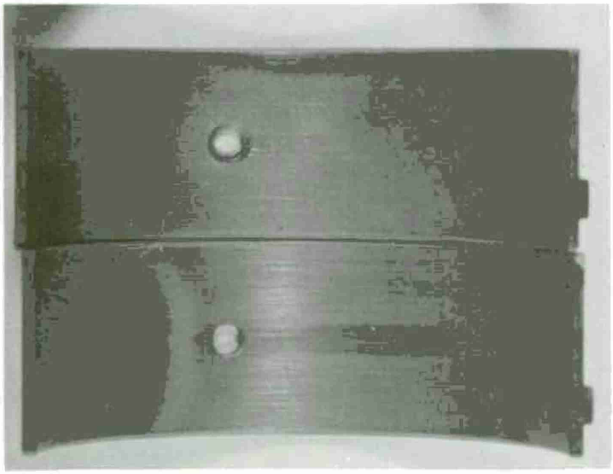


FIGURE 10. INSOLUBLE RESINS IN FINAL DRAIN SAMPLES, M-151 ROAD TEST

the engine oil viscosity at acceptable levels under no-drain operation. However, an increase in oil consumption would tend to help control this viscosity increase.

Reduced blowby and reduced oil degradation should be reflected in a reduction in varnish and deposits in the engine. While both engines were very clean, indicative of the high quality level oil used during the tests, there were differences in deposits between the two engines. The average piston skirt and relief area demerit rating of the standard engine was 2.1 while the average demerit rating of the low-blowby modified engine was 0.6 for the skirts and 0.7 for the relief areas, where 0 is clean. The pistons were also rated using the AFLRL modified deposit rating method, which provides a single demerit number indication of the deposit levels on the piston ring zone and undercrown. The standard engine had an average rating, with the second ring groove excluded, of 210 while on the same basis, the modified engine had an average rating of 107, a lower and thus cleaner rating. The second ring groove was excluded from the rating because the elastomer seal behind the second rings of the low-blowby configuration made deposit determination difficult. Complete ratings are given in Appendix F.

Low Blowby Rings



Standard Rings

FIGURE 11. WEAR IN BABBIT OVERLAY, M-151 ROAD TEST

Wear in both engines was normal and acceptable, although the ring gap increases in the standard engine (Table 2) were greater than those of the modified engine, partially due to the difference in ring face materials. While the connecting rod bearings were normal in both engines, more of the babbit overlay in the highly loaded areas had been removed in the standard engine than in the modified engine (Figure 11). Iron and copper content of the used oil samples (Figure 12) show that while the iron contents were essentially equal by the end of the road test, there appears to be a difference in copper wear rates.

Correlation of Dynamometer and Vehicle Tests

Based on road load measurements and M-151 vehicle gear ratios, 100 hr of the dynamometer test cycle represent 5430 km or 3375 miles of vehicle operation. However, when comparisons are made of the amount and rate of engine oil degradation, the dynamometer cycle appears to be approximately twice as severe as the above mileage figures indicate. Based on the change in total acid and base numbers in the standard engine's oil compared to the results from the

TABLE 2. PISTON RING END GAP CHANGE, M-151 ROAD TEST

	Piston number											
	1			2			3			4		
	Ring No.			Ring No.			Ring No.			Ring No.		
	1	2t	2b	1	2t	2b	1	2t	2b	1	2t	2b
Standard, mm	0.229	0.203	—	0.178	0.305	—	0.127	0.254	—	0.127	0.229	—
Rings, (in.)	(0.009)	(0.008)	—	(0,007)	(0.012)	—	(0.005)	(0.010)	—	(0.005)	(0.009)	—
Low-Blowby, mm	0.102	0.102	0.076	0.152	0.178	0.127	0.152	0.152	0.178	0.127	0.102	0.178
Rings, (in.)	(0.004)	(0.004)	(0.003)	(0.006)	(0.007)	(0.005)	(0.006)	(0.006)	(0.007)	(0.005)	(0.004)	(0.007)

M-151 road tests, the dynamometer cycle degraded the oil at a rate of 10,940 km (6800 miles) per 100 test hours. When comparisons are made using the changes in oil viscosity at both 38°C (100°F) and 99°C (210°F), the oil appears to degrade at a rate such that 100 test hr is equivalent to 9800 km (6100 miles). Based on these two figures, the 225-hr dynamometer test represents 23,500 km (14,600 miles) of operation over the test course used.

SUMMARY OF RESULTS

The TRW, Inc. low-blowby ring package, by substantially reducing the amount of blowby entering the sump of the L-141 engine, significantly reduced oil degradation as evidenced by a smaller viscosity increase, reduced oxidation and nitration products in the drained oil, and lower deposit levels in the modified engine as compared to the standard engine. However, the oil viscosity in the modified engine, while increasing at half the rate of the standard engine, did not appear to be stabilizing at any constant value.

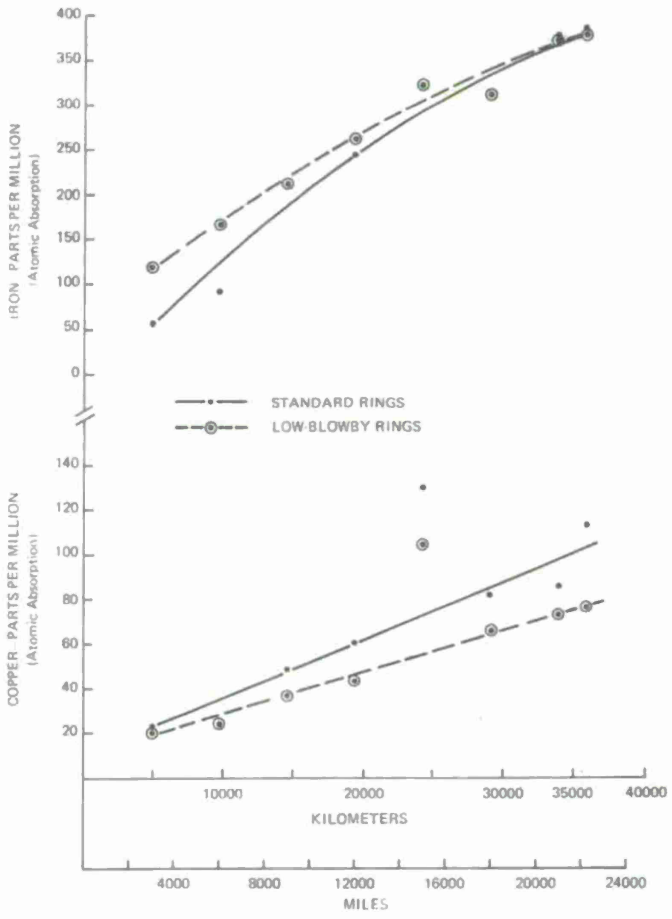


FIGURE 12. WEAR METALS CONTENT OF ENGINE OILS, M-151 ROAD TEST

This piston ring system, while not allowing unlimited no-drain operation, does appear to extend the useful life of the oil without any performance or economy penalty. No performance loss was detected during dynamometer evaluations, and the overall fuel mileage for both vehicles averaged 13.5 liters per 100 km (17.4 miles/gal.) during the road test. If the engine oil drain criteria is a 35-percent increase in the viscosity at 99°C (210°F), then the standard engine's oil would be drained at approximately 22,500 km (14,000 miles), which slightly exceeds the drain interval of 19,300 km (12,000 miles) presently specified. Based on this same 35-percent viscosity increase criteria, the modified engine's oil would be drained at approximately 35,400 km (22,000 miles), a 57-percent increase in oil life and greater than the expected 33,000 km (20,000 mile) vehicle lifetime. However, these drain intervals apply only to

this accelerated mileage accumulation cycle and would require further evaluation before being applied to vehicles with other driving cycles.

The main and connecting rod bearings of both engines were acceptable, although the babbit layer had been removed. Other wear was also acceptable, and the engines were considered to be in good condition, although the modified engine had a lower level of deposits.

CONCLUSIONS

- The TRW, Inc. low-blowby piston rings substantially reduce the amount of blowby reaching the oil sump of the L-141 engine without reducing engine power or increasing fuel or oil consumption.

- This reduction in blowby decreases the engine oil degradation 50 percent or more during medium- to high-temperature operation as evidenced by oil oxidation and nitration, viscosity increase, and engine deposits.

- These low-blowby rings, in conjunction with a high quality level single-grade MIL-L-2104C/ MIL-L-46152 qualified oil, appear to make no-drain operation feasible for the 33,000-km (20,000-mile) expected life of the M-151 vehicle when operated in a temperate zone where seasonal drains are unnecessary.

- However, these rings do not allow no-drain operation in areas where wide temperature extremes dictate seasonal drains of the single-grade oil required by the M-151 vehicle lubrication order.

RECOMMENDATIONS

- Further evaluation of this piston ring package should be carried out under more varied climatic and operating conditions. In particular, cold weather operation with its associated low-temperature oil contamination and degradation should be examined.

- Studies should be conducted using multiviscosity and synthetic engine oils in conjunction with these rings as methods of eliminating seasonal oil drain requirements.

- Studies of blowby control in diesel engines should be initiated to determine the potential benefits with this engine type. Particular attention should be given to reductions in soot contamination.

REFERENCES

1. E.C. Owens, S.J. Lestz, R.D. Quillian, Jr., "Never-Drain Engine Oil Technology," USAFLRL Interim Report No. 49, ADA012777, June 1975.

2. J.T. Gray, "Study and Evaluation in the Field of Environmental Pollution Relative to the Utilization of Army Material," USAFLRL Final Summary Report No. 50, AD003335, Contract DAAD05-72-C-0053, October 1974.

3. Status Report of AFLRL Position Paper on Single Lubricant/Never-Drain Engine Oil Concept, Letter (File: F7-3672 and G3-7372) AFLRL to USAMERDC, STSFB-GL, dated 13 August 1974.

4. AFLRL Position Paper, "Single Lubricant/Never-Drain Engine Oil Concept," Letter (File F7-3672 and G3-7372) AFLRL to USAMERDC, STSFB-GL, dated 17 October 1974.

5. U.S. Military Specification MIL-L-2104C, "Lubricating Oil, Internal Combustion Engine, Tactical Service," November 1970.

6. U.S. Military Specification MIL-L-46152, "Lubricating Oil, Internal Combustion Engine, Administrative Service," November 1970.

7. Contract No. DAAD05-72-C-0053, U.S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia 22060.

8. Federal Specification VV-G-001690A, "Gasoline, Low Lead or Unleaded," April 1974.

9. J. O'Flaherty, R.J. O'Rorke, Sr., "Fuel and Oil Costs for Army Equipment," Contract No. DA44-188-ARO-1, AD844049.

APPENDIX A

TEST LUBRICANT, MIL-L-2104C/MIL-L-46152

APPENDIX A

Test Lubricant, MIL-L-2104C/MIL-L-46152

Property	REO-203 (CCL-L-759)	Specification Requirements MIL-L-2104C/MIL-L-46152
Viscosity, cS		
at 99°C (210°F)	12.61	9.6 - 12.9
at 38°C (100°F)	121.6	Report
Viscosity Index	94	75 min
Flash Point, °C (°F)	241 (465)	218(425)min
Pour Point, °C (°F)	-21 (-5)	-18(0) max
Gravity, °API	27.4	Report
Carbon Residue, %	1.19	Report
Sulfated Ash, %	0.93	Report
Total Acid Number	3.3	Report
Total Base Number	5.4	Report
Additive Content, %wt		
Zinc	0.093	Report
Calcium	0.24	Report
Barium	nil	Report

APPENDIX B

COMMERCIAL TEST FUELS

APPENDIX B

Test Fuels, Commercial

Property	Laboratory Fuel	Road Test Fuel	VV-G-001690 Specification
Fuel code	AL-5473	AL-5894	
Gravity, °API	57.5	59.8	
Reid Vapor Pressure	8.9	11.1	11.5 max
Distillation, °C (°F)			
IBP	31 (88)	29 (85)	
10% evap.	53 (127)	45 (113)	60 (140) max
20% evap.	68 (155)	56 (132)	
50% evap.	106 (222)	94 (201)	116 (240) max
90% evap.	162 (323)	168 (335)	185 (365) max
EP	182 (360)	202 (395)	225 (437) max
Recovered, %	97.4	98.0	
Residue, %	1.1	1.0	
Loss, %	1.5	1.0	
Existent Gum, mg/100 ml			
Unwashed	95.7*	3.5	10.0 max
Washed	0.0	1.8	4.0 max
Oxidation Stability, min.	>1440	350	240 min
Sulfur, wt %	0.004	0.028	0.10 max
Lead, g/gal	0.0084	0.004	0.05 max
Phosphorus, mg/gal	0.96	<0.04	5.0 max
Aromatic, % (FIA)	32.2	28.9	45.0 max
Olefins, % (FIA)	3.6	18.6	Report
Saturate, % (FIA)	64.2	52.5	
Research Octane No.	93.2	92.7	
Motor Octane No.	82.9	82.0	

*High value for unwashed existent gum due to additive package. Allowable under specification.

APPENDIX C

DYNAMOMETER TEST CYCLE

APPENDIX C

Dynamometer Test Cycle

Controlled Variables	Cycle Phase 1	2	3*
Time per cycle, mins.	30	60	30
Engine speed, rpm	2000	2800	600
Load, N-m (ft-lb)	129 (95)	127 (94)	0
Water temp., °C (°F)	82 (180)	82 (180)	38 (100)

*Every fourth idle cycle omitted for oil sampling and consumption measurements.

This cycle was repeated for 16 hours, followed by an eight hour shut-down. This twenty-four hour cycle is repeated as necessary to obtain the desired test duration. Of the total 24 hours, only 15 hours is to be counted as engine operating time.

Cycle Significance:

Based on road load measurements from an M-151 vehicle loaded to its rated cross-country capacity of 250 kg (550 lbs), the 2000 rpm phase was intended to represent 56 kilometers per hour (35 mph) high load operation while the 2800 rpm period was to represent 80 kilometer per hour (50 mph) level road operation. Based on this, a 100 hour period of operation would represent 5430 kilometers (3375 miles) traveled.

Based on the change in total acid and base numbers in the standard engine's oil, and compared to the results from the M-151 road tests, this dynamometer test degraded the oil at a rate of 6800 miles per 100 test hours. When comparisons are made using the changes in oil viscosity at 38°C (100°F) and 99°C (210°F), the oil appears to degrade at a rate such that 100 test hours is equivalent to 6100 miles.

APPENDIX D
DYNAMOMETER TESTS RESULTS

TEST 1—150 HOURS

STANDARD PISTON RINGS

Fuel: VV-G-001690A (AL-5473)
Lubricant: REO-203
Date Completed: 23 December 1974

TEST 1
Standard Piston Rings
150 hours

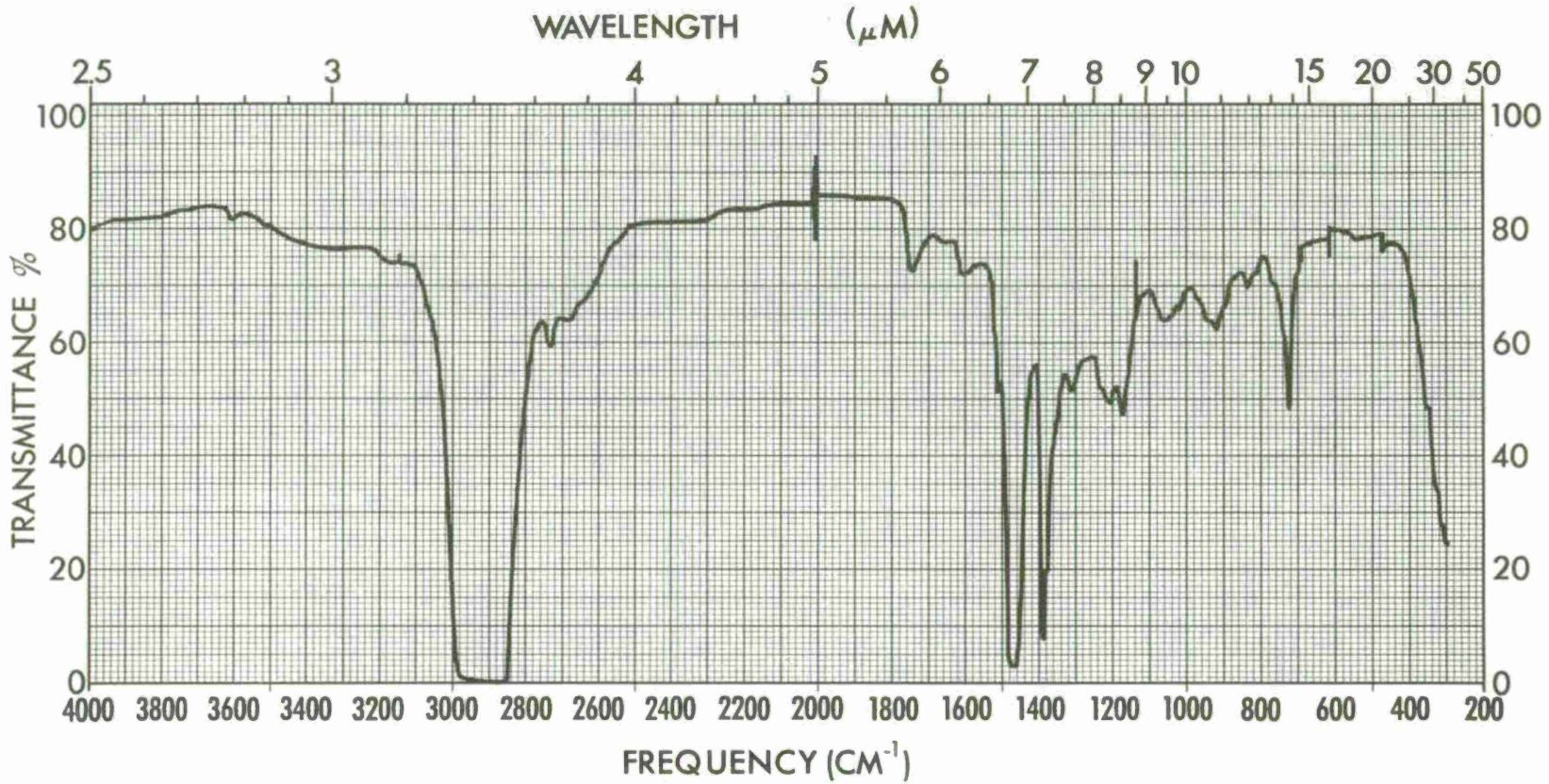
Summary of Operating Conditions

2800 RPM Mode	AVG	MIN	MAX
Torque, N-m (ft-lb)	127 (94)	126 (93)	130 (96)
Power, OBS, Kilowatts (BHp)	37.5 (50.3)	36.9 (49.5)	38.2 (51.3)
Specific Fuel Cons., kg/kW-hr (lbs/BHp-hr)	.331 (.544)	.259 (.425)	.351 (.577)
Blowby @ 49C (120F), m^3/h (cu.ft./hr)	1.35 (47.8)	.932 (32.9)	1.57 (55.4)
Sump Temperature, C (F)	121 (250)	114 (238)	124 (256)
Manifold Vacuum, kPa (In. Hg.)	10.5 (3.1)	9.1 (2.7)	11.1 (3.3)
2000 RPM Mode	**AVG**	**MIN**	**MAX**
Torque, N-m (ft-lb)	129 (95)	114 (84)	133 (98)
Power, OBS, kilowatts (BHp)	26.9 (36.1)	23.8 (32.0)	27.8 (37.3)
Specific Fuel Cons., kg/kW-hr (lbs/BHp-hr)	.352 (.579)	.274 (.450)	.369 (.606)
Blowby @ 49C (120F), m^3/h (cu.ft./hr)	1.00 (35.3)	.770 (27.2)	1.25 (44.3)
Sump Temperature, C (F)	102 (216)	88 (191)	107 (225)
Manifold Vacuum, kPa (In.Hg.)	10.1 (3.0)	9.5 (2.8)	11.8 (3.5)
600 RPM Mode	**AVG**	**MIN**	**MAX**
Torque, N-m (ft-lb)	0	0	0
Power, OBS, kilowatts (BHp)	0.0	0.0	0.0
Blowby @ 49C (120F), m^3/h (cu.ft./hr)	.249 (8.8)	.198 (7.0)	.331 (11.7)
Sump Temperature, C (F)	62 (144)	51 (124)	69 (156)
Manifold Vacuum, kPa (In. Hg.)	60.4 (17.9)	51.0 (15.1)	68.2 (20.2)

TEST 1
Standard Piston Rings
150 hours

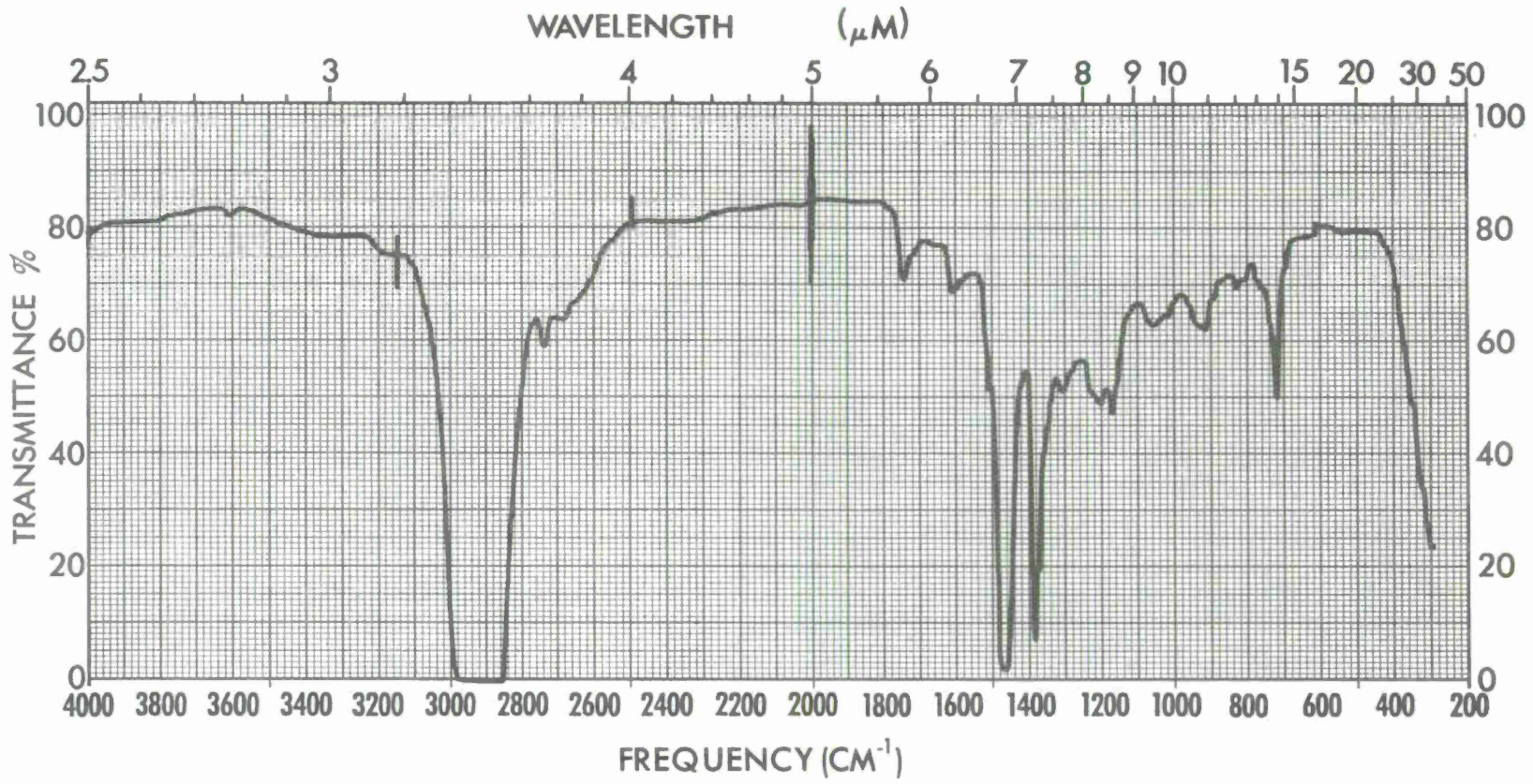
Used Oil Analysis

Test Hour	Viscosity, cS 38°C(100°F)	99°C(210°F)	Total Acid No.	Total Base No.	Fuel Dilu.,%	Water Dilu.,%
New	121.6	12.61	2.97	5.08	-	-
15	104.15	11.56	2.90	4.69	1.4	0.05
30	107.49	11.86	3.27	4.97	0.4	
45	112.02	11.93	3.27	4.69	0.6	
60	116.03	12.23	3.43	4.81	0.4	
75	117.82	12.40	2.85	4.97	nil	0.05
90	122.55	12.66	3.38	4.97		
105	123.70	12.86	3.27	4.13		
120	127.34	13.08	3.12	4.13		
135	130.47	13.32	3.38	4.69		
150	138.74	13.84	3.96	4.24	0.8	0.03



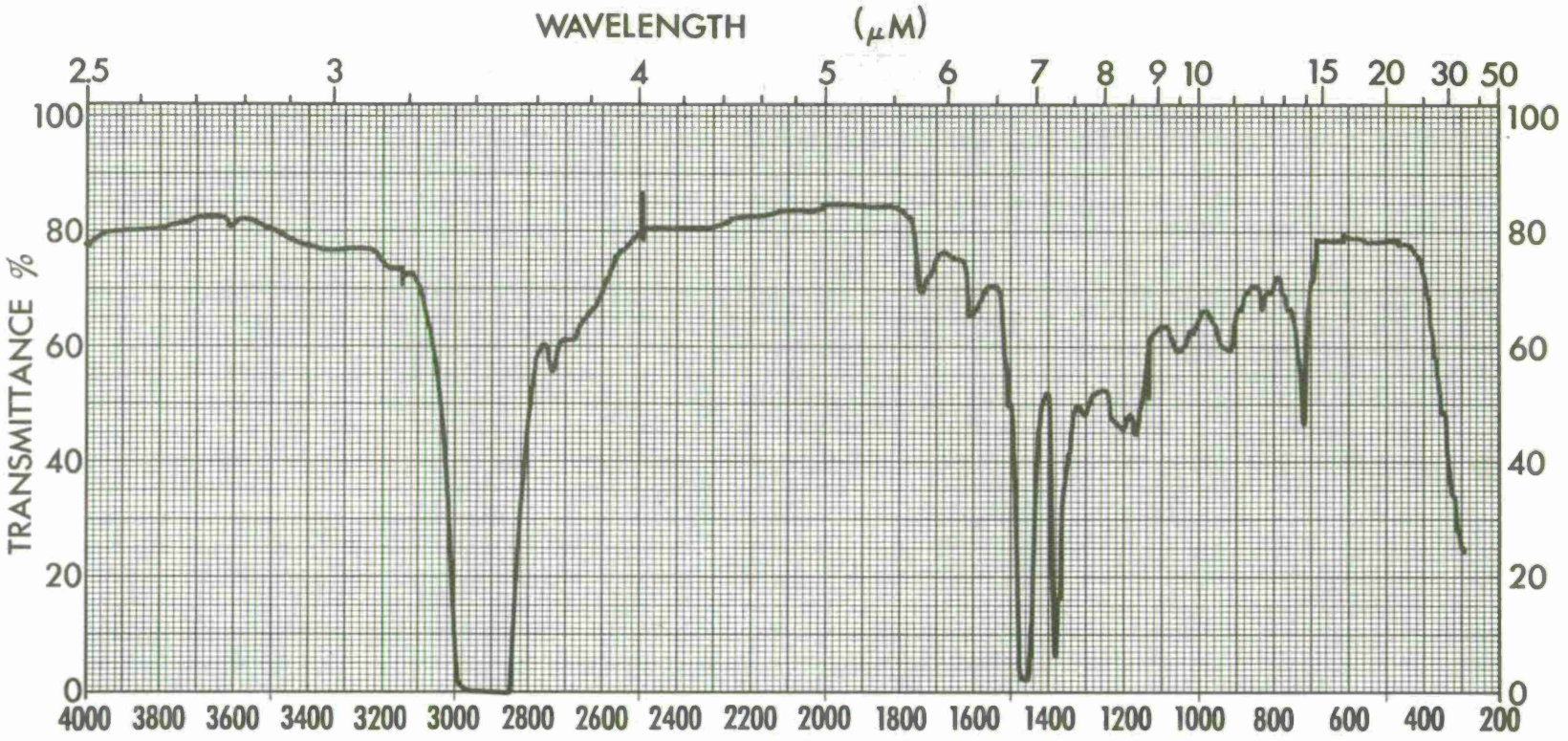
SPECTRUM NO. 569	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
NEW	PURITY	2.	
	PHASE	DATE 12-16-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



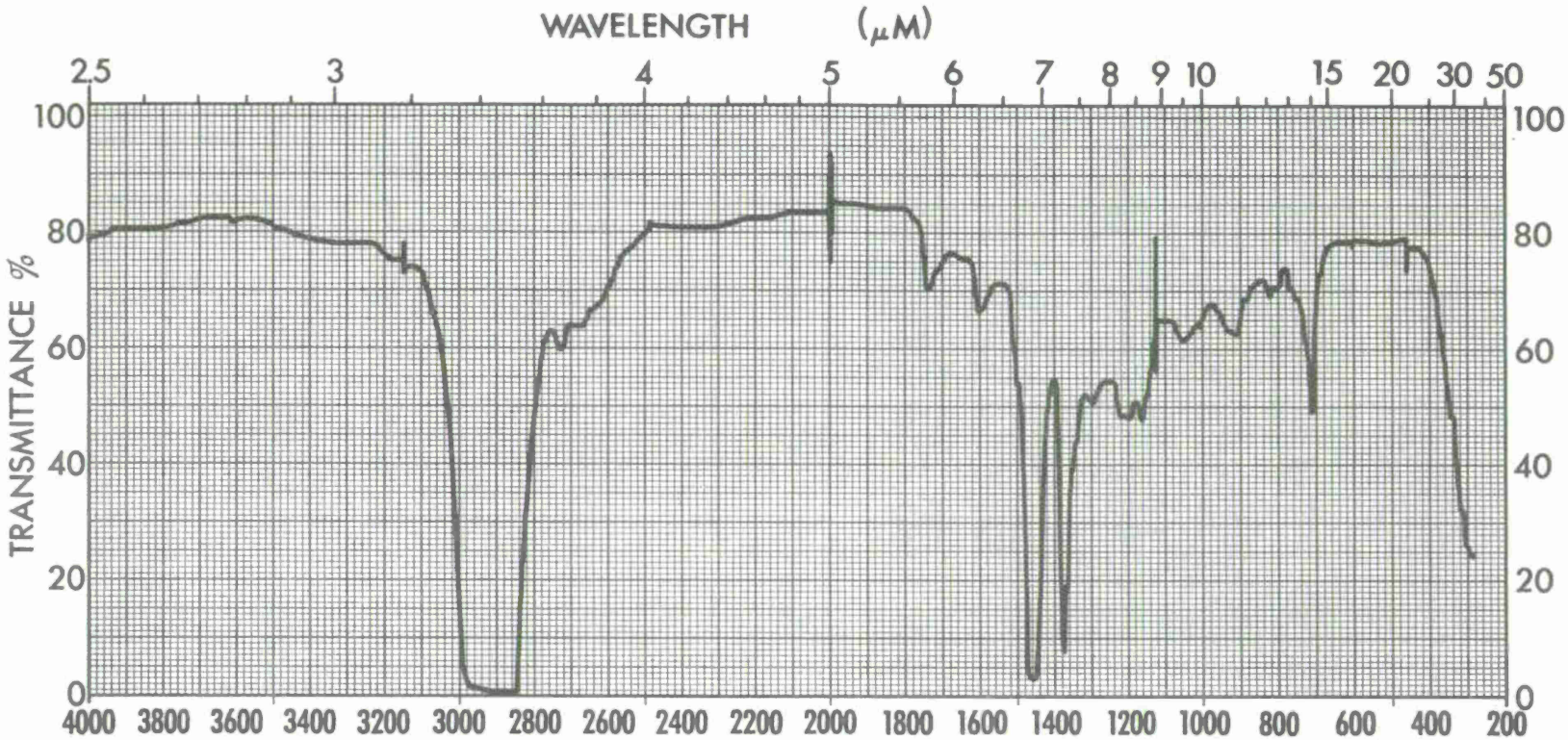
SPECTRUM NO. 570	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
15 HR	PURITY	2.	
	PHASE	DATE 12-16-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



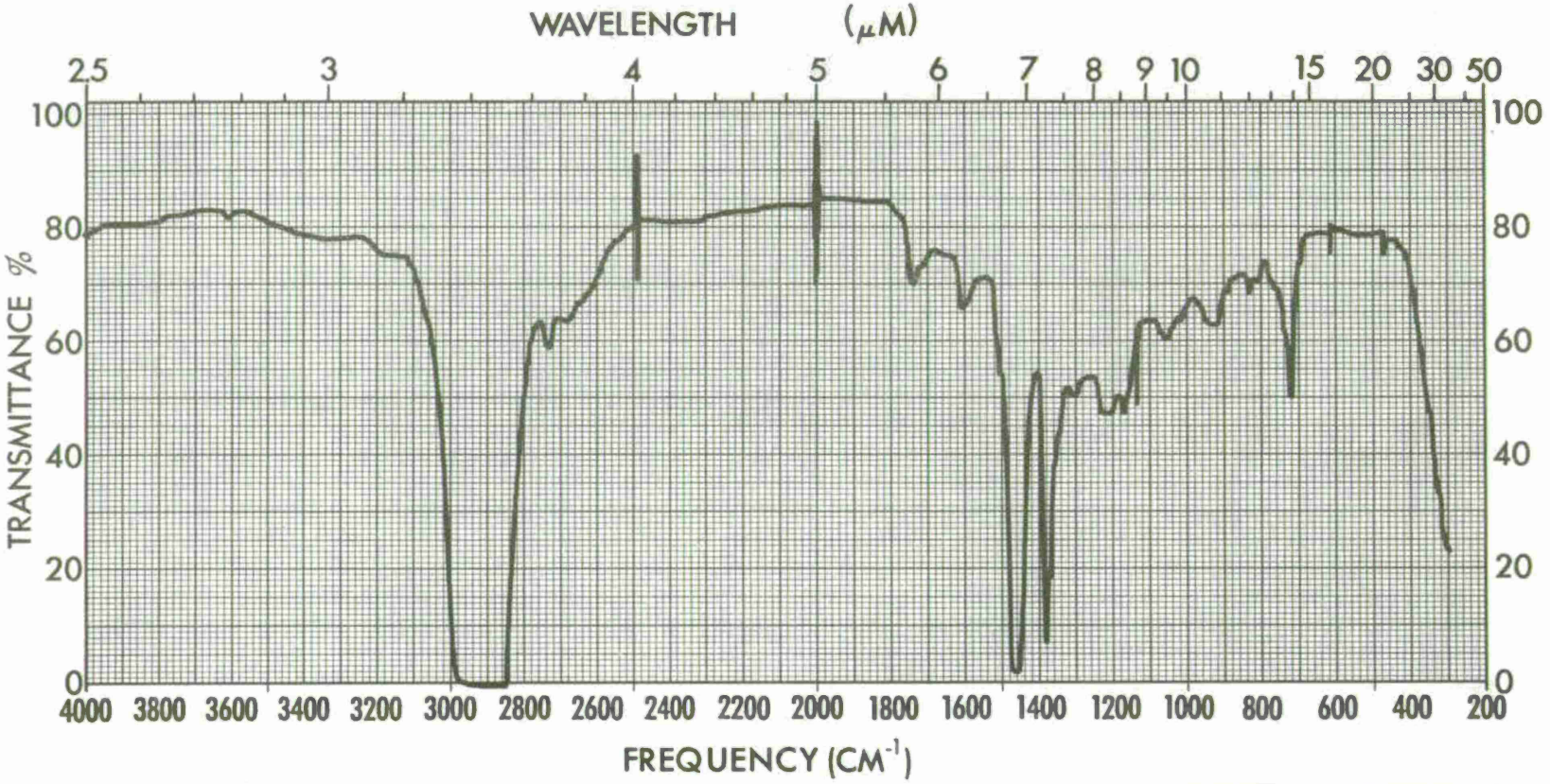
SPECTRUM NO. 571	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
30-HR	PURITY	2.	
	PHASE	DATE 12-16-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. SAMPLE



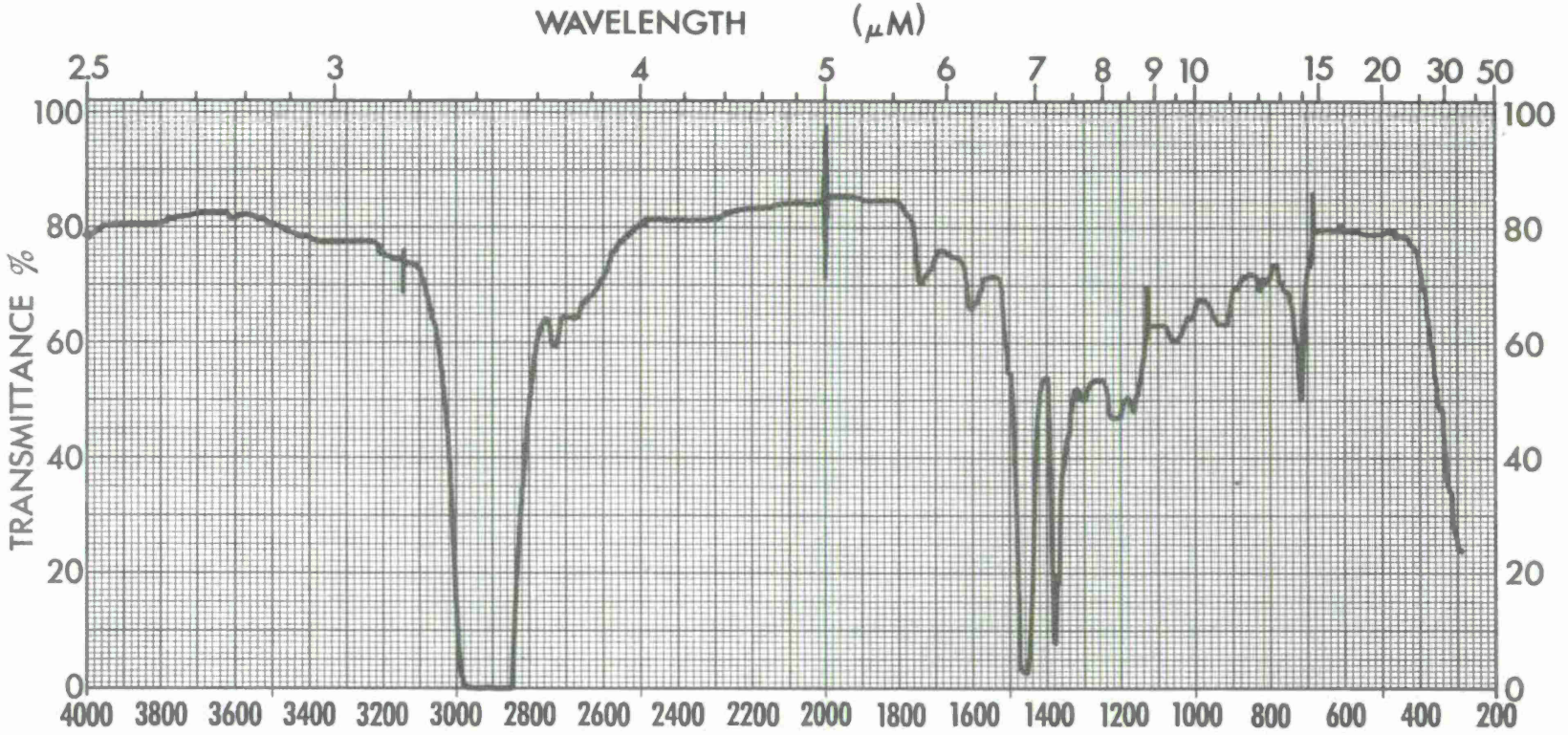
SPECTRUM NO. 572	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
45 HR	PURITY	2.	
	PHASE	DATE 12-17-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. SAMPLE



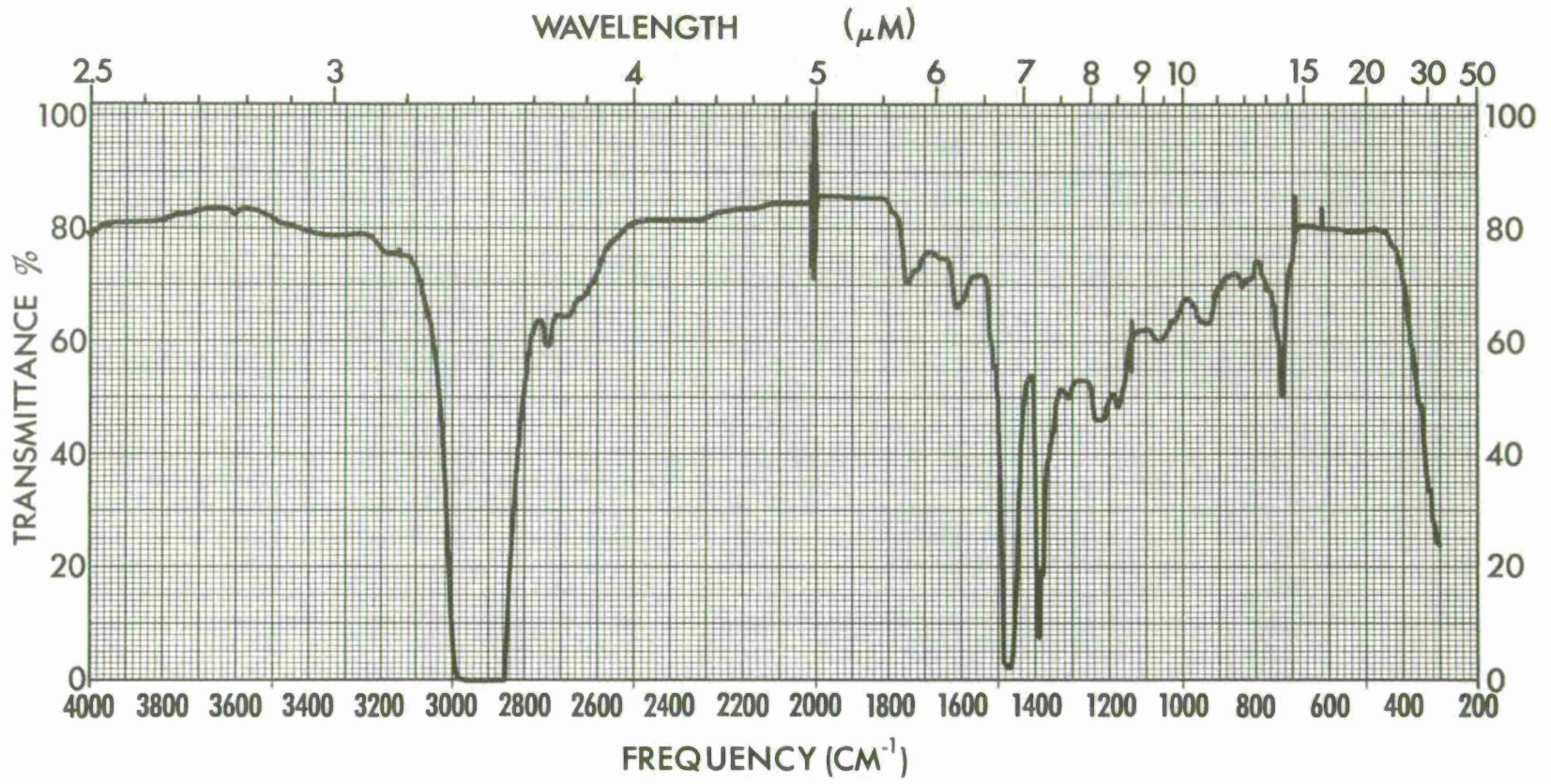
SPECTRUM NO. 573	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
60 HR	PURITY	2.	
	PHASE	DATE 12-17-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



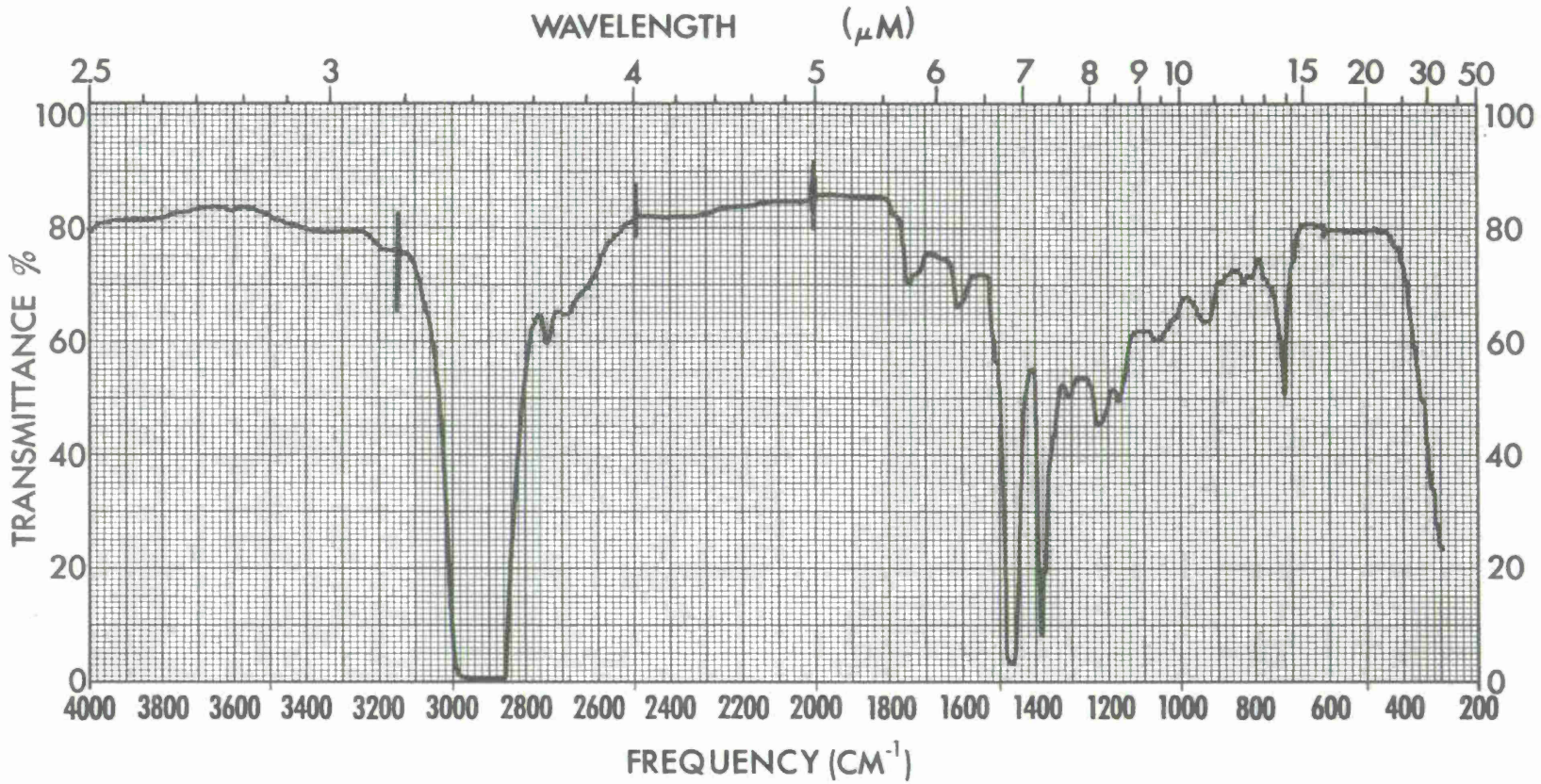
SPECTRUM NO. 574	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
75 HR	PURITY	2.	
	PHASE	DATE 12-17-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. SAMPLE



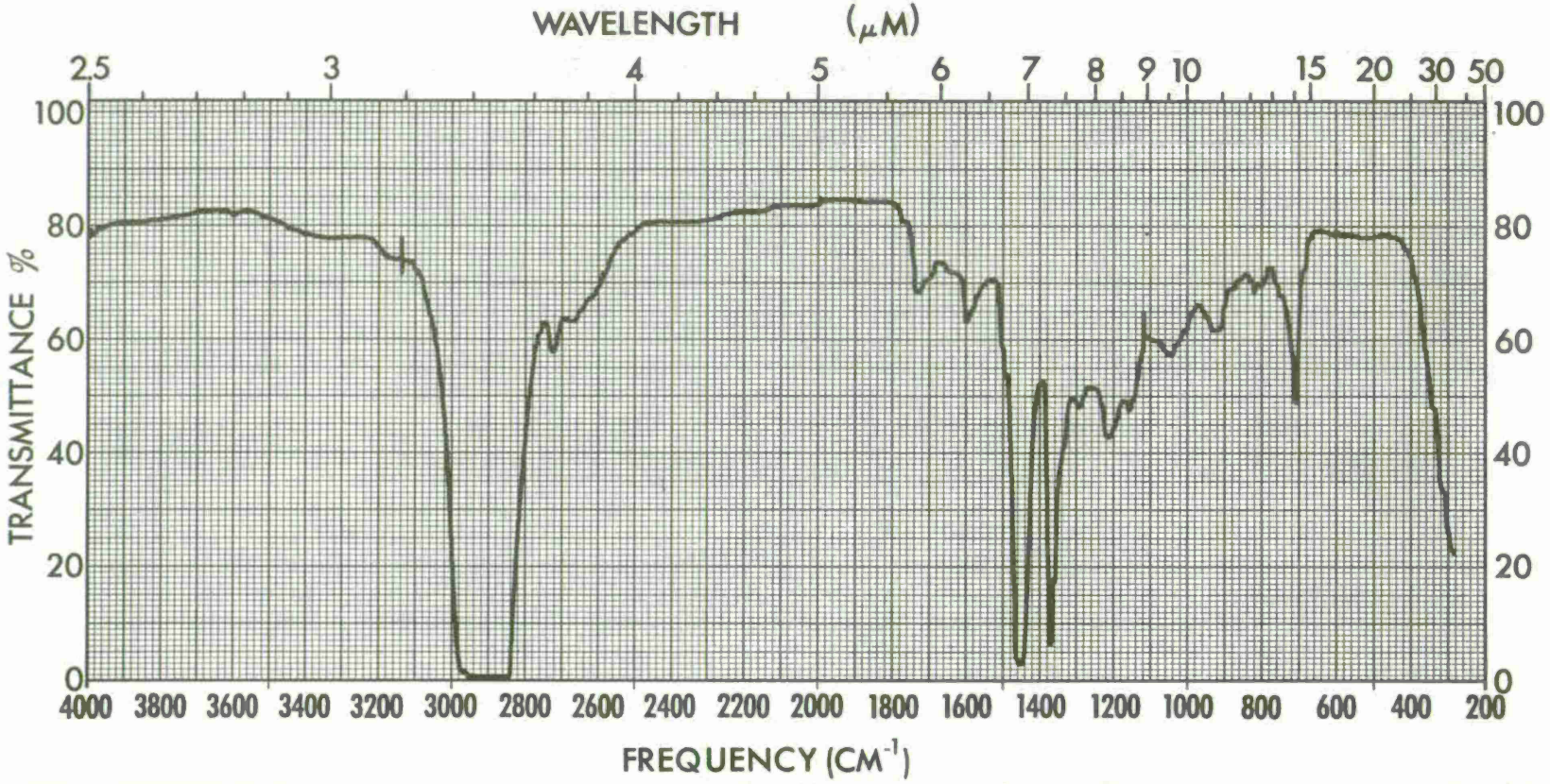
SPECTRUM NO. 575	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
90 HR	PURITY	2.	
	PHASE	DATE 12-17-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



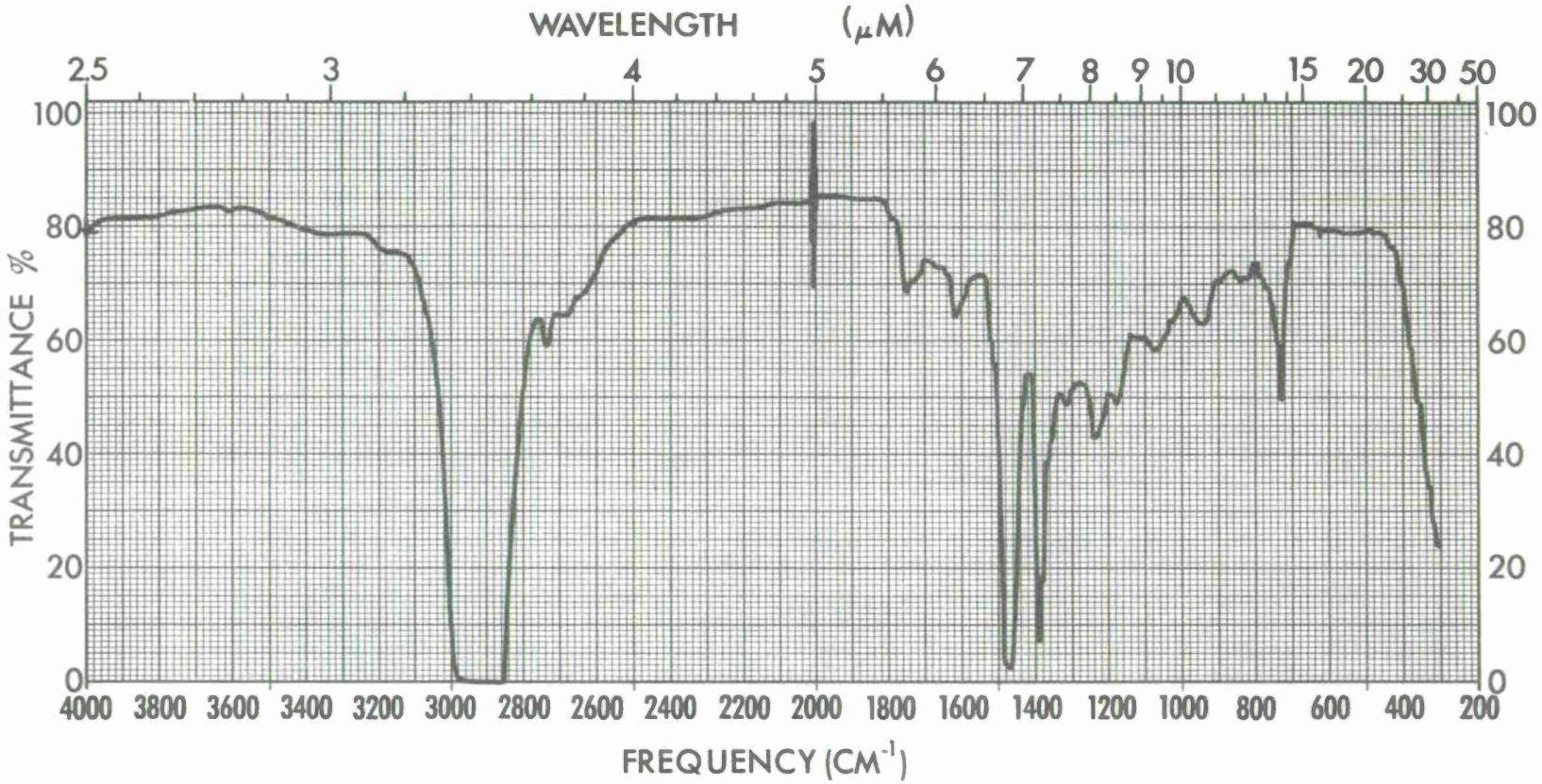
SPECTRUM NO. 576	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
105 HR	PURITY	2.	
	PHASE	DATE 12-18-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



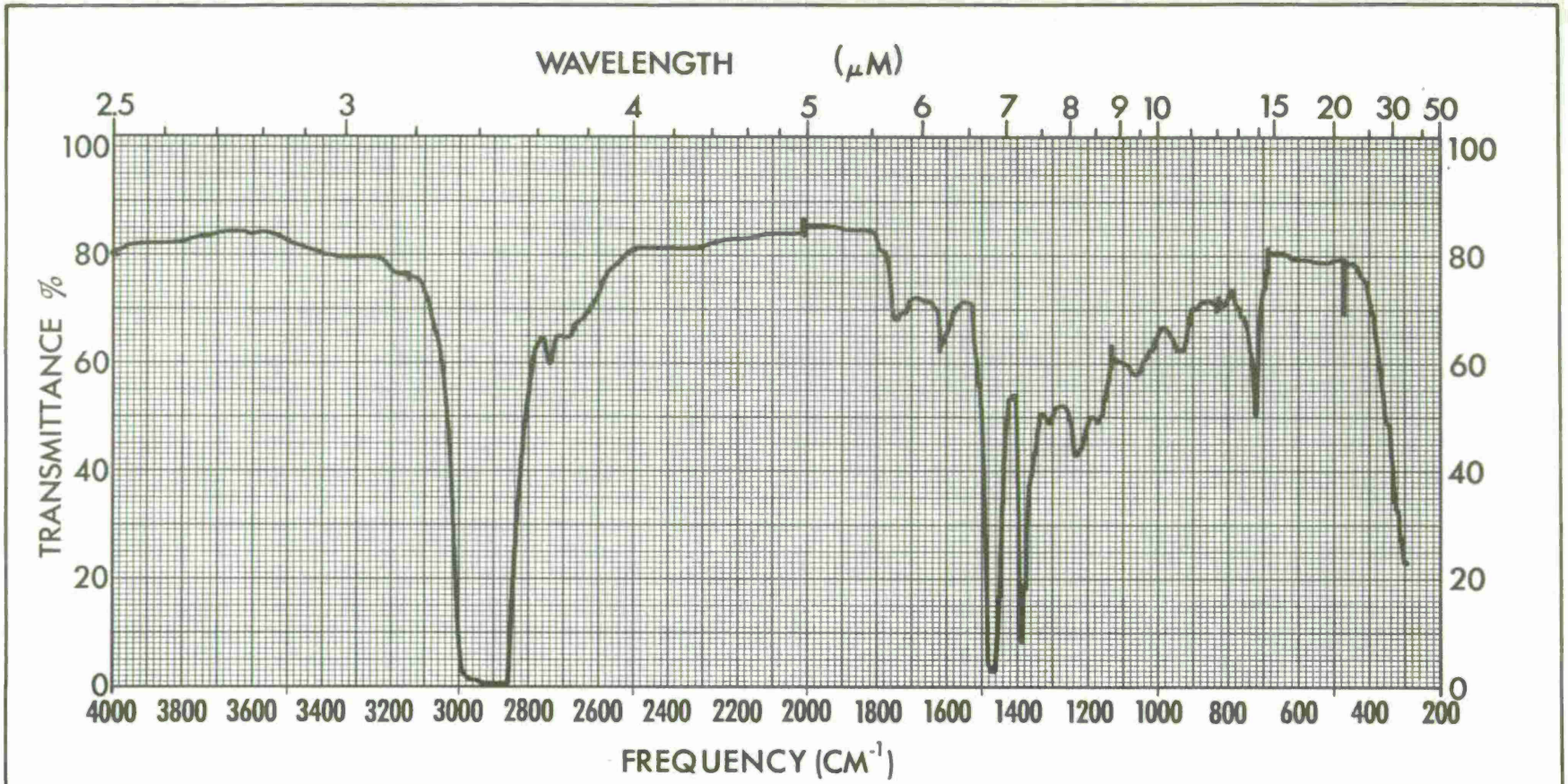
SPECTRUM NO. 577	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
120 HR	PURITY	2.	
	PHASE	DATE 12-19-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



SPECTRUM NO. 578	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
135 HR	PURITY	2.	
	PHASE	DATE 12-20-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



SPECTRUM NO. 579	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
150 HR	PURITY	2.	
	PHASE	DATE 12-26-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____

TEST 1
Standard Piston Rings
150 hours

Oil Consumption

Test Hours	Oil Consumed kilograms (lbs)	Sample Removed kilograms (lbs)	Oil Added kilograms (lbs)
7.5	0	0	0
15	.005 (.01)	.045 (.10)	.050 (.11)
22.5	0	0	0
30	0	.036 (.08)	.036 (.08)
37.5	.009 (.02)	0	.009 (.02)
45	0	.032 (.07)	.032 (.07)
52.5	0	0	0
60	.027 (.06)	.041 (.09)	.068 (.15)
67.5	0	0	0
75	0	.036 (.08)	.036 (.08)
82.5	.132 (.29)	0	.132 (.29)
90	0	.041 (.09)	.041 (.09)
97.5	0	0	0
105	0	.036 (.08)	.036 (.08)
112.5	0	0	0
120	0	.055 (.12)	.055 (.12)
127.5	.027 (.06)	0	.027 (.06)
135	0	.045 (.10)	.045 (.10)
142.5	0	0	0
150	0	0	0

initial fill - 3.91 kg (8.60 lbs)
final drain - 3.10 kg (6.82 lbs)
change in filter wt. - 0.27 kg (0.60 lbs)
total oil consumed - 0.74 kg (1.62 lb)

Piston Ring Measurements

Test No.1 — Ring Configuration: Standard
Engine Model: L-141 — Serial No.: 5029085 — Dates: 12/4/74 - 1/2/75
Fuel: AL-5473 — Lubricant: REO-203 — Observer: Jungman

End Gaps, cm (inches)

Piston Ring		Piston Number 1	2	3	4
Top Ring	before	.056 (.022)	.043 (.017)	.048 (.019)	.053 (.021)
	after	.056 (.022)	.048 (.019)	.053 (.021)	.056 (.022)
	change	0	.005 (.002)	.005 (.002)	.003 (.001)
Second Ring	before	.058 (.023)	.061 (.024)	.056 (.022)	.061 (.024)
	after	.061 (.024)	.061 (.024)	.058 (.023)	.061 (.024)
	change	.003 (.001)	0	.003 (.001)	0

Side Clearance, cm (inch x 10^{-3})

Piston Ring		Piston Number 1	2	3	4
Top Ring	before	.005 (2)	.008 (3)	.005 (2)	.005 (2)
	after	.008 (3)	.008 (3)	.005 (2)	.005 (2)
	change	.003 (1)	0	0	0
Second Ring	before	.008 (3)	.008 (3)	.005 (2)	.008 (3)
	after	.008 (3)	.005 (2)	.005 (2)	.008 (3)
	change	0	-.003 (-1)	0	0

TEST NO. 1
PISTON AND CYLINDER BORE MEASUREMENTS

Measurement	Location	Cylinder Bore, cm (in.) Piston Number 1	2	3	4
		1.1 cm from Top			
Transverse	before	9.8461 (3.8764)	9.8486 (3.8774)	9.8453 (3.8761)	9.8450 (3.8760)
	after	9.8461 (3.8764)	9.8478 (3.8771)	9.8453 (3.8761)	9.8458 (3.8763)
	change	0	−0.0008 (−0.0003)	0	0.0008 (0.0003)
Longitudinal	before	9.8463 (3.8765)	9.8476 (3.8770)	9.8453 (3.8761)	9.8455 (3.8762)
	after	9.8463 (3.8765)	9.8471 (3.8768)	9.8450 (3.8760)	9.8455 (3.8762)
	change	0	−0.0005 (−0.0002)	−0.0003 (−0.0001)	0
		5.87 cm from Top			
Transverse	before	9.8463 (3.8765)	9.8476 (3.8770)	9.8453 (3.8761)	9.8453 (3.8761)
	after	9.8463 (3.8765)	9.8471 (3.8768)	9.8450 (3.8760)	9.8453 (3.8761)
	change	0	−0.0005 (−0.0002)	−0.0003 (−0.0001)	0
Longitudinal	before	9.8450 (3.8760)	9.8473 (3.8769)	9.8450 (3.8760)	9.8453 (3.8761)
	after	9.8445 (3.8758)	9.8468 (3.8767)	9.8448 (3.8759)	9.8453 (3.8761)
	change	−0.0005 (−0.0002)	−0.0005 (−0.0002)	−0.0003 (−0.0001)	0

TEST 2–225 HOURS

LOW-BLOWBY PISTON RINGS

Fuel: VV-G-001690A (AL-5473)
Lubricant: REO-203
Date Completed: 23 January 1975

TEST 2

Low Blowby Piston Rings
225 Hours
Summary of Operating Conditions

2800 RPM MODE	AVG	MIN	MAX
Torque, n-m (ft-lb)	126(93)	123(91)	130(96)
Power, OBS, kilowatts (BHp)	37.1(49.7)	36.2(48.5)	38.3(51.3)
Specific Fuel Cons., kg/kW-hr (lbs/BHp-hr)	.330(.542)	.295(.485)	.348(.572)
Blowby @ 49C (120F), m^3/hr (cu.ft./hr)	.275(9.7)	.105(3.7)	.643(22.7)
Sump Temperature, C (F)	116(241)	98(208)	119(246)
Manifold Vacuum, kPa (in.hg.)	10.1(3.0)	8.1(2.4)	12.8(3.8)

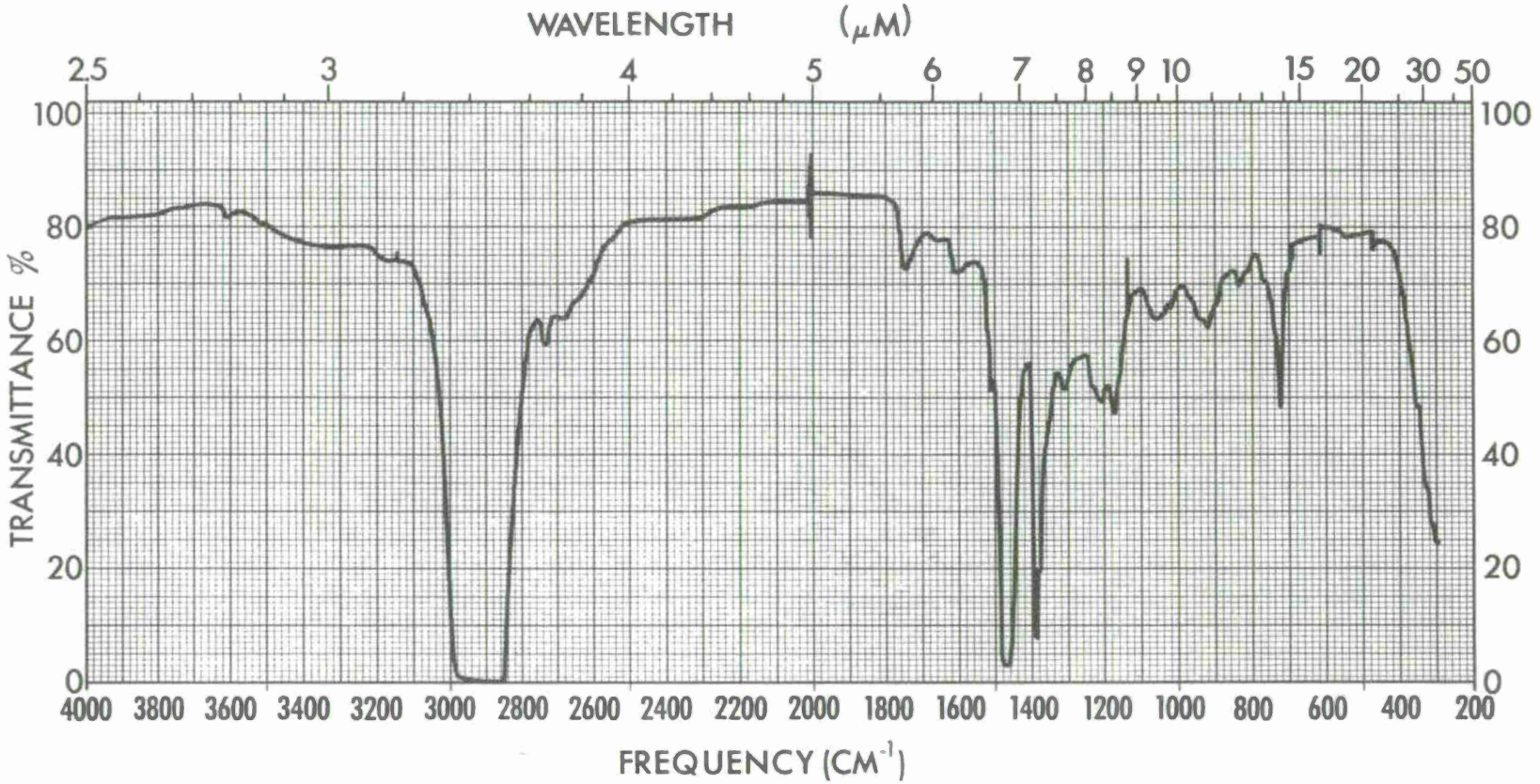
2800 RPM MODE	AVG	MIN	MAX
Torque, n-m (ft-lbs)	129(95)	123(91)	138(102)
Power, OBS, kilowatts (BHp)	27.1(36.3)	25.9(34.7)	28.9(38.7)
Specific Fuel Cons., kg/kW-hr (lbs/BHP-hr)	.344(.566)	.295(.485)	.370(.608)
Blowby @ 49C (120F), m^3/hr (cu.ft./hr)	.246(8.7)	0.0	.827(29.2)
Sump Temperature, C (F)	97(207)	90(194)	102(216)
Manifold Vacuum, kPa (in.hg.)	9.5(2.8)	6.1(1.8)	11.1(3.3)

600 RPM MODE	AVG	MIN	MAX
Torque, n-m (ft-lb)	0	0	0
Power, OBS, kilowatts (BHp)	0.0	0.0	0.0
Blowby @ 49C (120F), m^3/hr (cu.ft./hr)	.062(2.2)	0.0	.509(18.0)
Sump Temperature, C (F)	59(139)	51(123)	73(164)
Manifold Vacuum, kPa (in.hg.)	62.8(18.6)	57.1(16.9)	65.8(19.5)

TEST 2
Low Blowby Piston Rings
225 hours

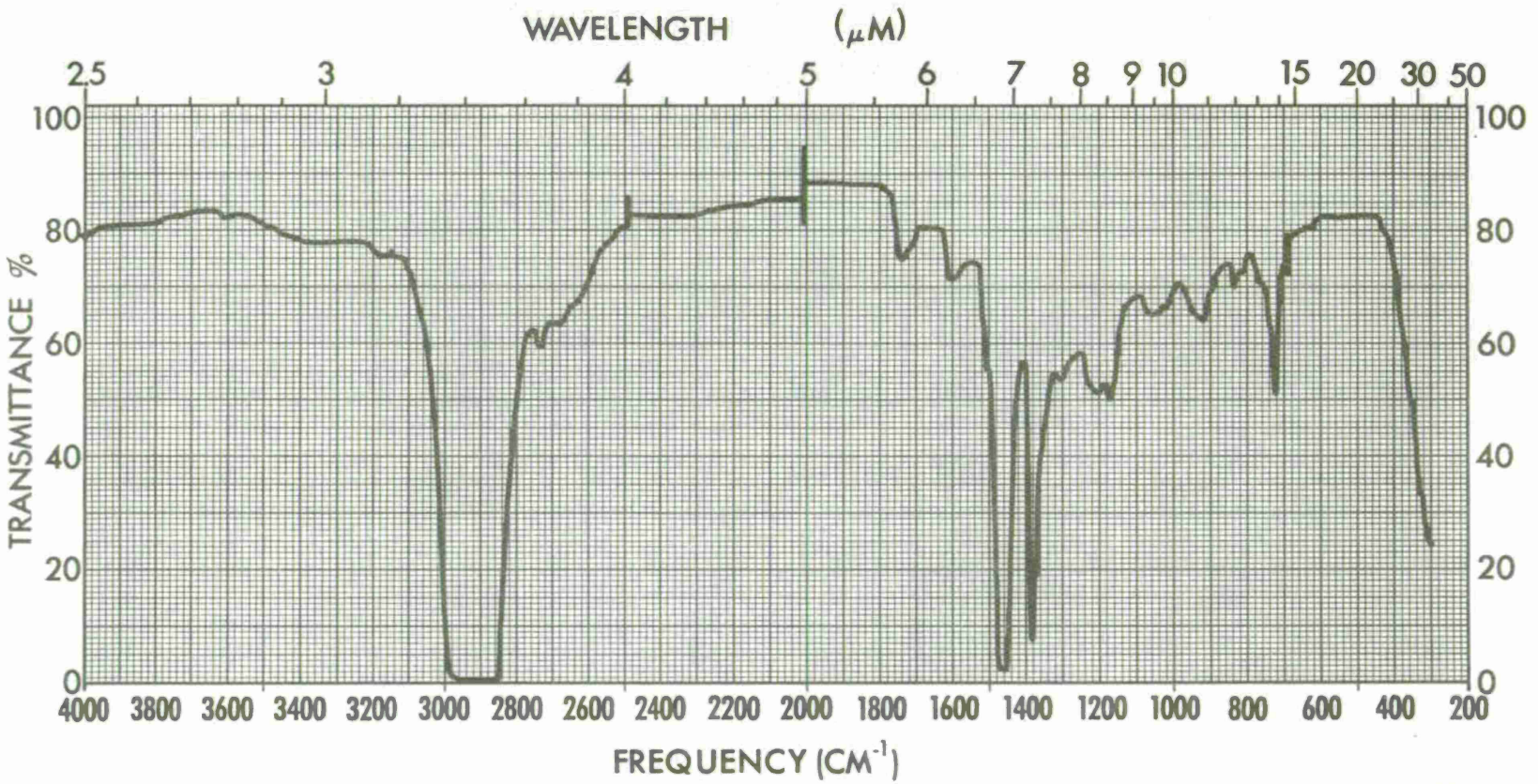
Used Oil Analysis

Test Hour	Viscosity, cS 38°C(100°F)	Viscosity, cS 99°C(210°F)	Total Acid No.	Total Base No.	Insolubles, w/coag. Pentane	Insolubles, w/coag. Benzene
New	121.6	12.61	2.97	5.08	—	—
15	108.03	11.68	3.37	4.81	0.0	0.0
30	111.93	12.01	3.40	4.86	0.01	0.02
45	113.94	12.09	3.45	5.14	0.03	0.03
60	115.73	12.24	3.78	4.40	0.06	0.03
75	121.20	12.60	3.98	4.51	0.05	0.03
90	125.38	12.97	3.82	4.86	0.05	0.02
105	128.17	13.08	3.40	4.73	0.04	0.03
120	131.73	13.36	3.56	4.95	0.05	0.03
135	134.78	13.52	4.20	4.92	0.07	0.07
150	139.41	14.03	4.30	4.68	0.07	0.06
165	141.05	14.13	3.82	4.59	0.08	0.08
180	143.86	14.28	4.30	4.75	0.10	0.06
195	148.55	14.41	4.02	5.05	0.09	0.06
210	144.91	14.30	3.93	4.49	0.09	0.06
225	141.52	14.13	3.93	4.49	0.11	0.08



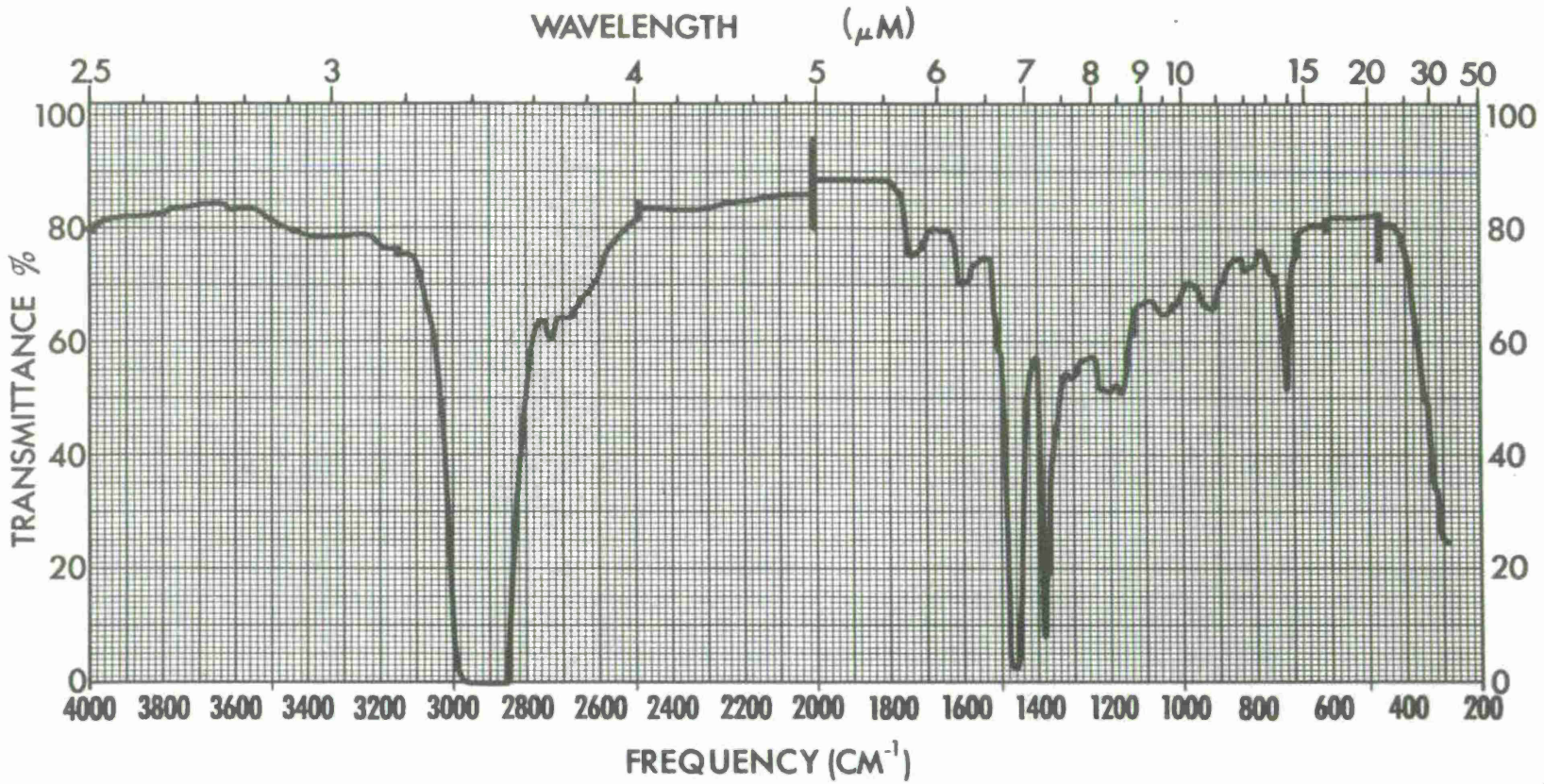
SPECTRUM NO. 569	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
NEW	PURITY	2.	
	PHASE	DATE 12-16-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



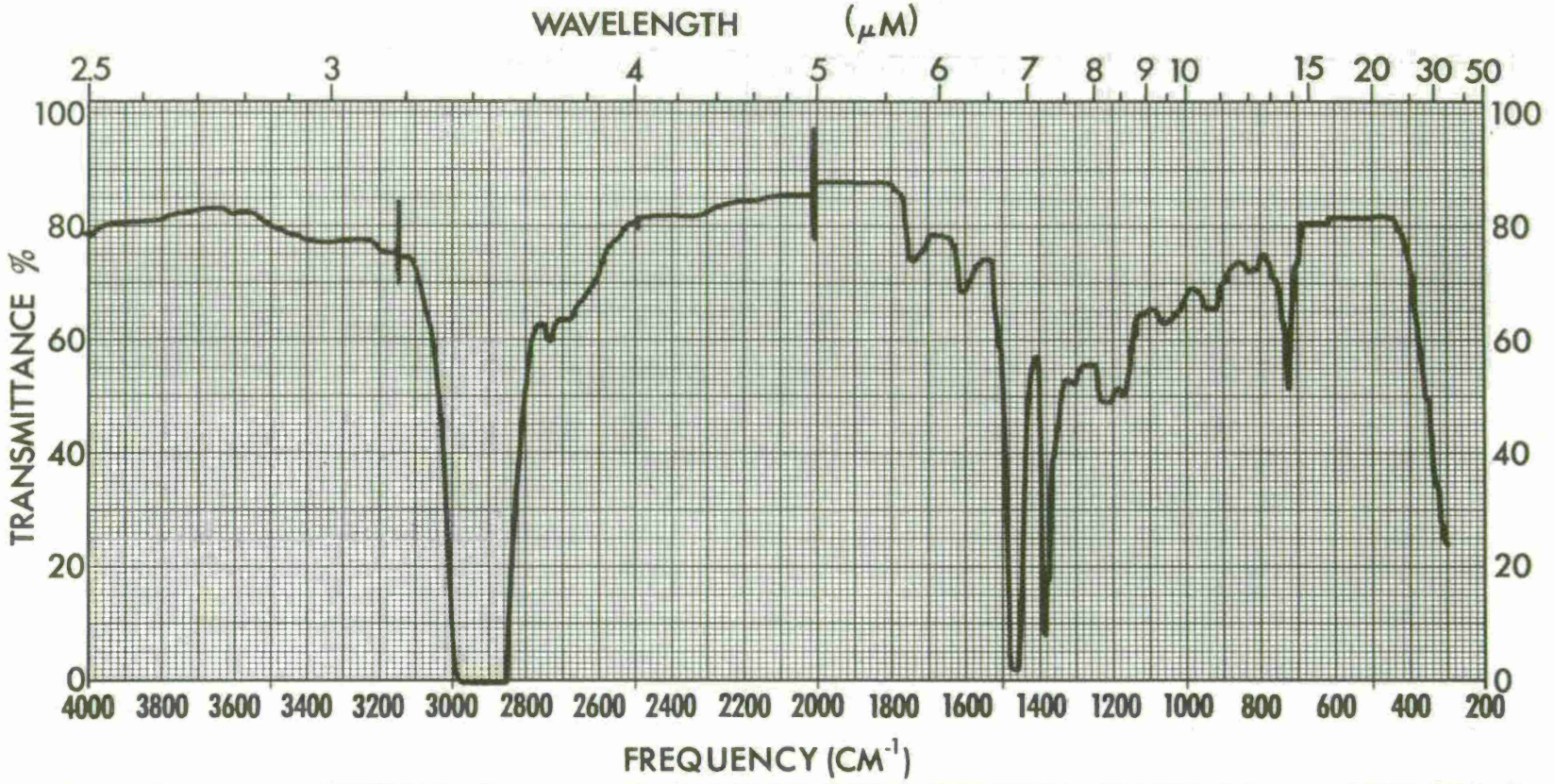
SPECTRUM NO. 594	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
15 HR	PURITY	2.	
	PHASE	DATE 2-7-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



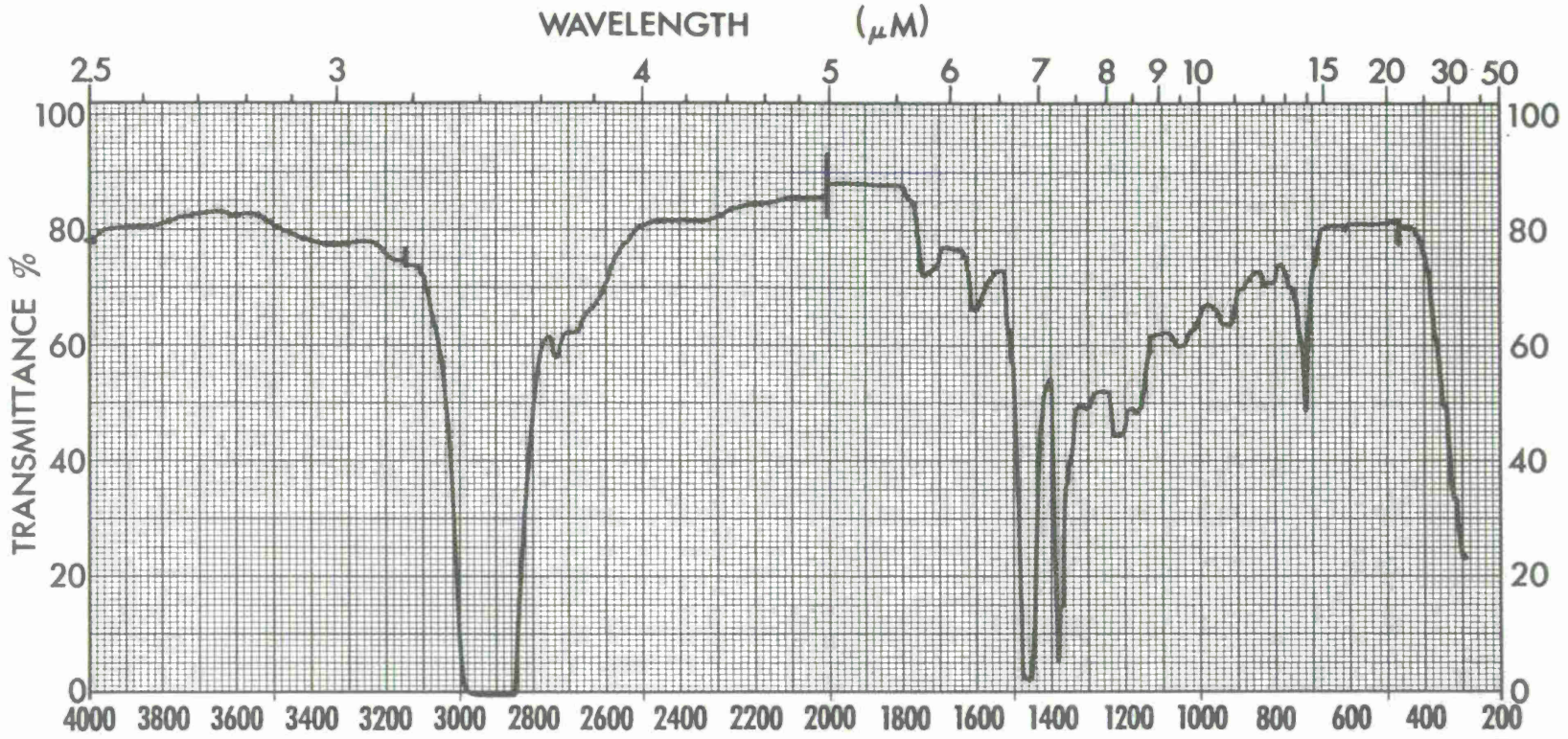
SPECTRUM NO. 595	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
45 HR	PURITY	2.	
	PHASE	DATE 2-7-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



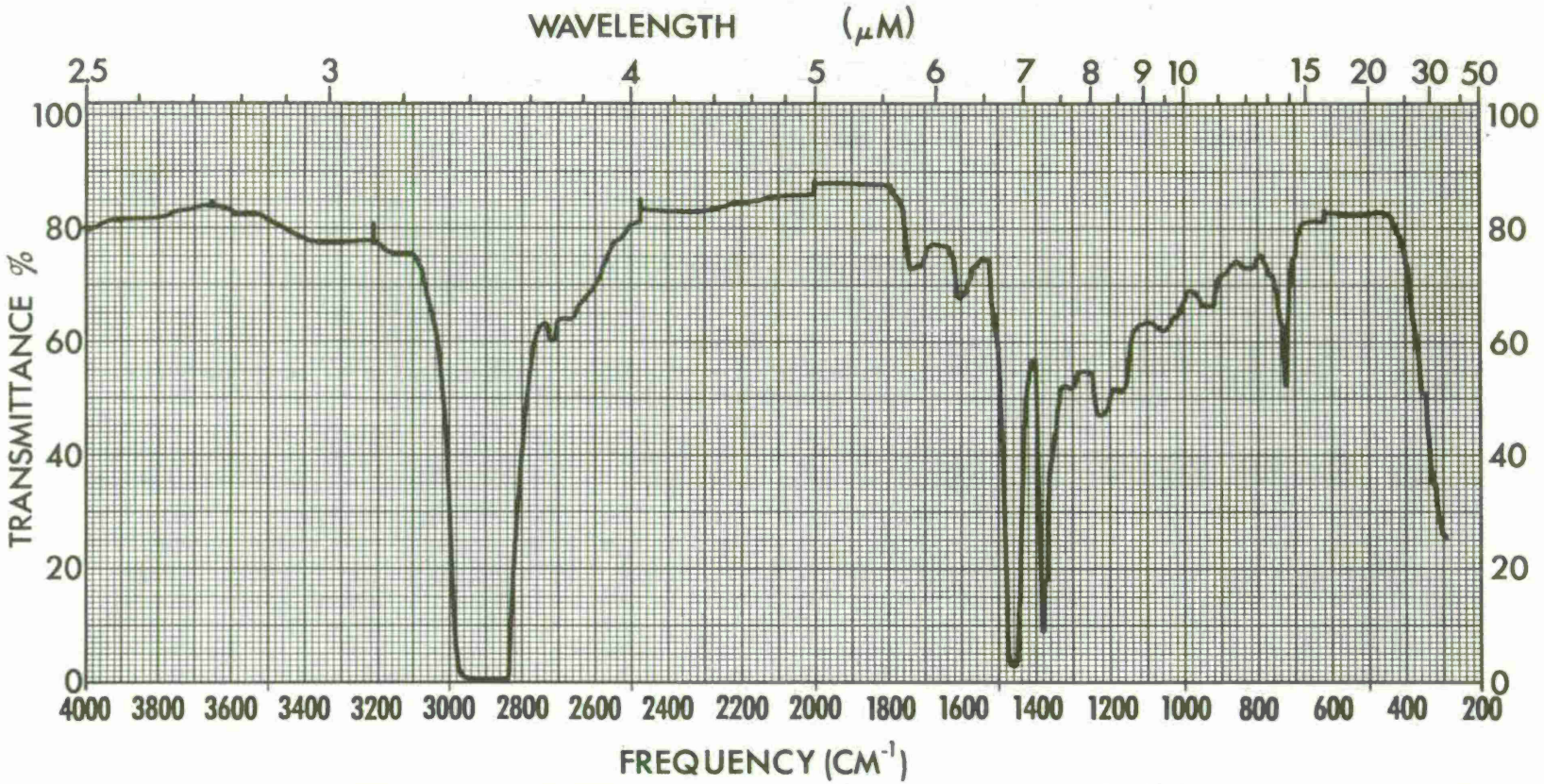
SPECTRUM NO. 596	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
75 HR	PURITY	2.	
	PHASE	DATE 2-7-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



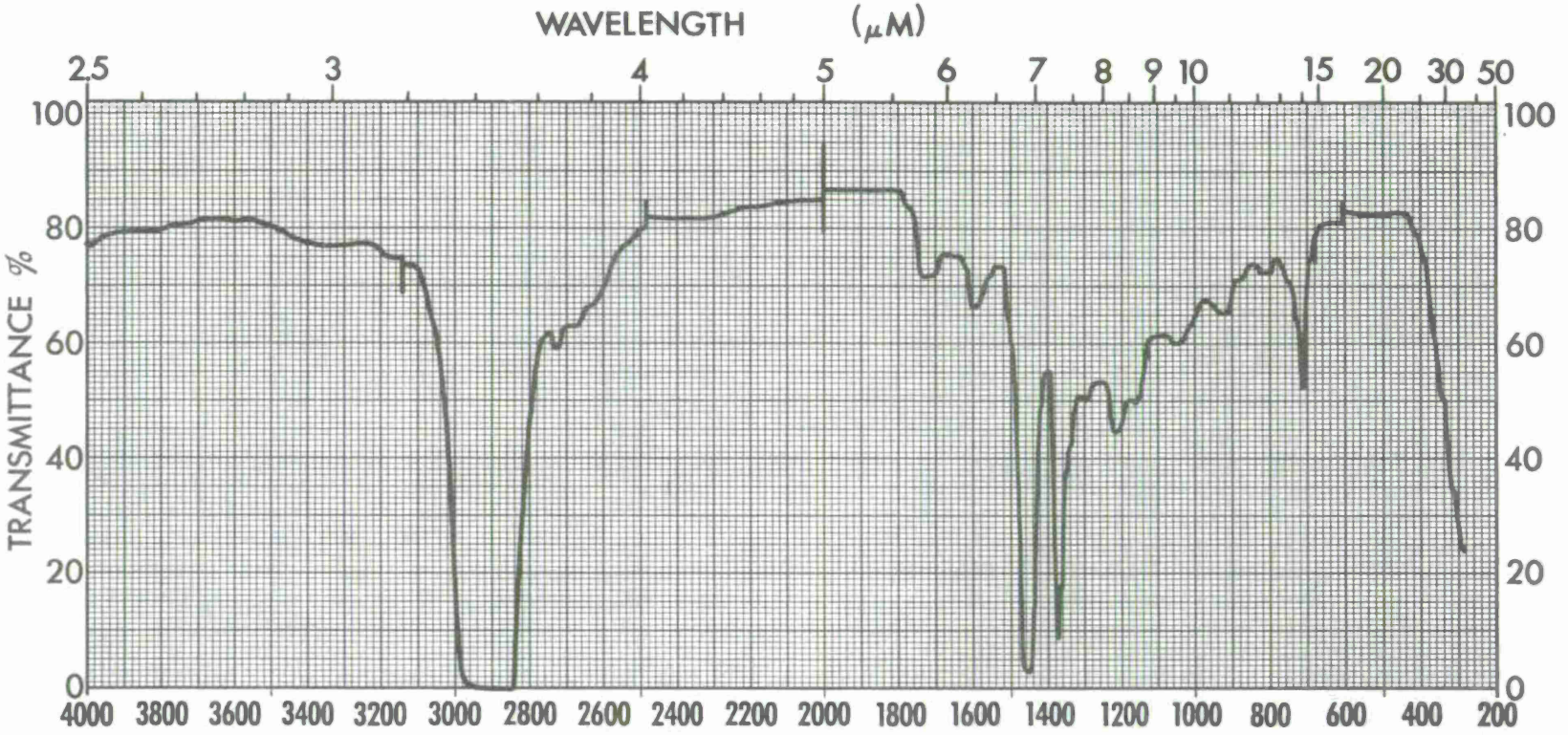
SPECTRUM NO. 597	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
105 HR	PURITY	2.	
	PHASE	DATE 2-7-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



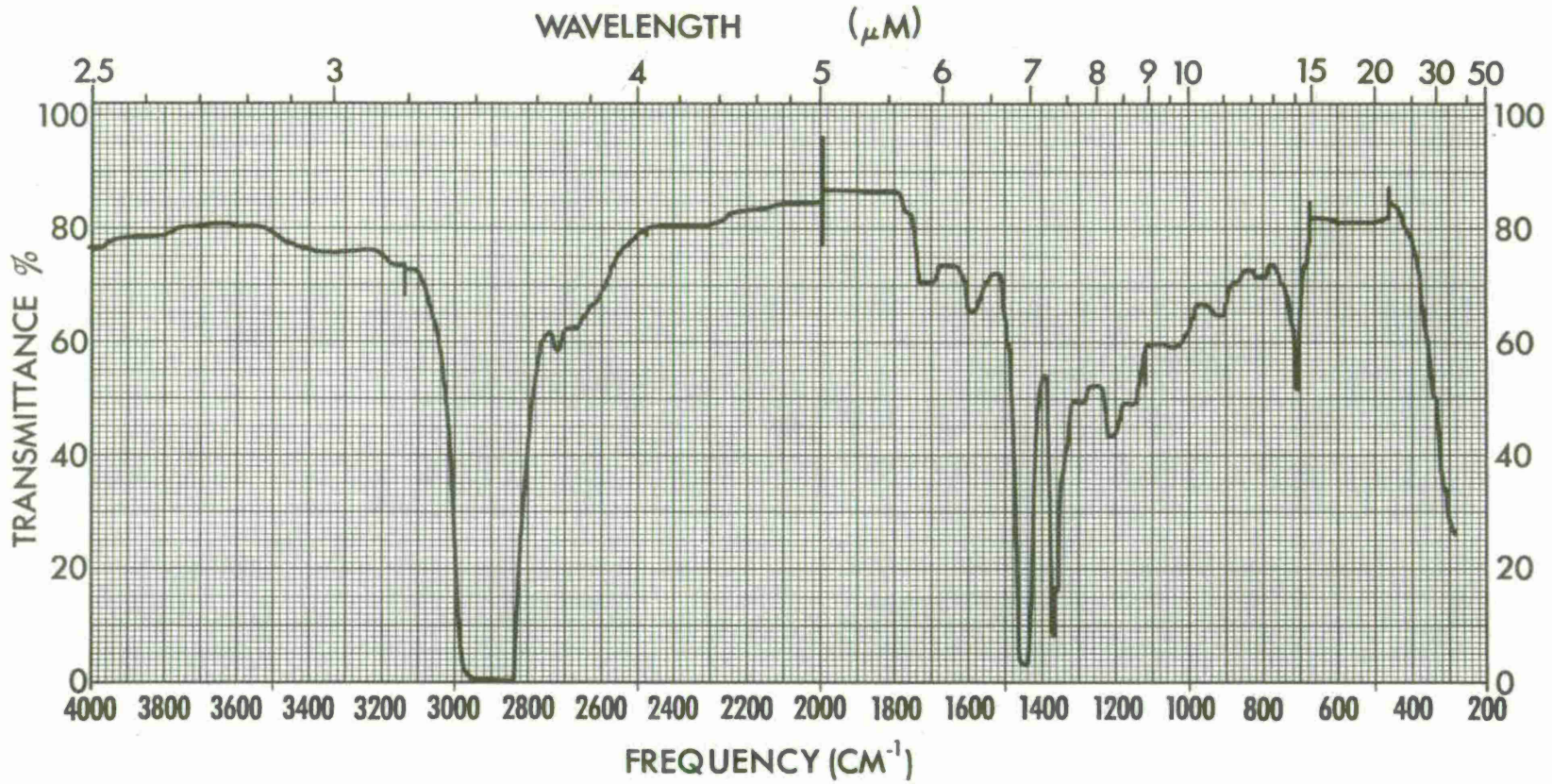
SPECTRUM NO. 598	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
135 HR	PURITY	2.	
	PHASE	DATE 2-10-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



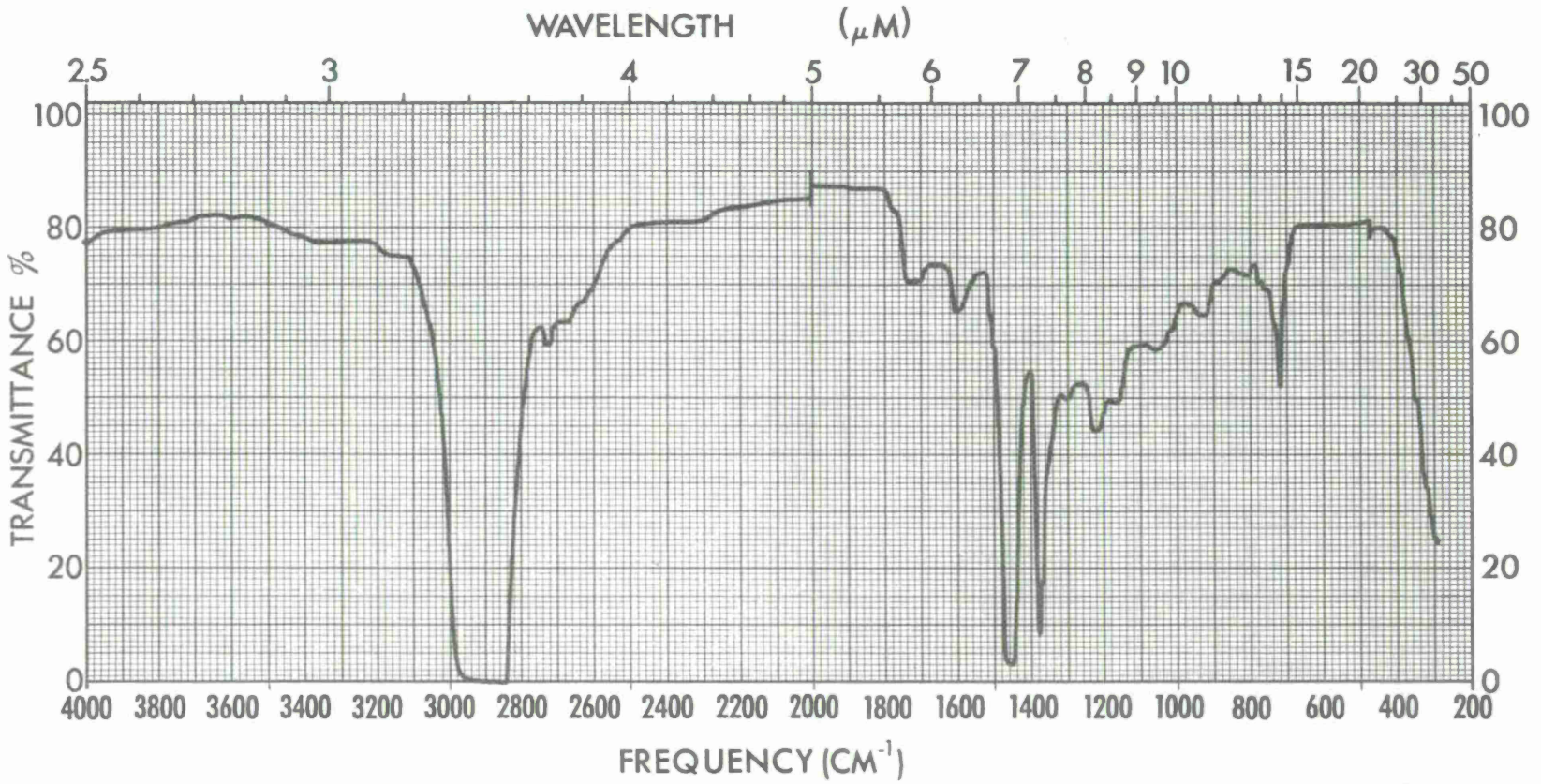
SPECTRUM NO. 599	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
165 HR	PURITY	2.	
	PHASE	DATE 2-10-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. SAMPLE



SPECTRUM NO. 600	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
195 HR	PURITY	2.	
	PHASE	DATE 2-10-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



SPECTRUM NO. 601	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
225 HR	PURITY	2.	
	PHASE	DATE 2-10-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____

TEST 2

Low Blowby Piston Rings
225 Hours

Oil Consumption

Test Hours	Oil Consumed Kilograms (lbs)	Sample Removed Kilograms (lbs)	Oil Added Kilograms (lbs)
7.5	0	0	0
15	.08 (.17)	.07 (.15)	.13 (.29)
22.5	0	0	0
30	0	.05 (.12)	.05 (.12)
37.5	0	0	0
45	.04 (.08)	.05 (.11)	.09 (.19)
52.5	0	0	0
60	.02 (.04)	.04 (.10)	.06 (.14)
67.5	0	0	0
75	.02 (.05)	.05 (.11)	.07 (.16)
82.5	0	0	0
90	.10 (.21)	.05 (.11)	.14 (.32)
97.5	0	0	0
105	0	.05 (.12)	.05 (.12)
112.5	.05 (.11)	0	.05 (.11)
120	.08 (.17)	.04 (.10)	.12 (.27)
127.5	0	0	0
135	.03 (.07)	.05 (.12)	.09 (.19)
142.5	.01 (.02)	0	.01 (.02)
150	.15 (.33)	.04 (.09)	.19 (.42)
157.5	.04 (.08)	0	.04 (.08)
165	.09 (.19)	.05 (.12)	.14 (.31)
172.5	0	0	0
180	.10 (.21)	.04 (.08)	.13 (.29)
187.5	0	0	0
195	.16 (.35)	.05 (.12)	.21 (.47)
202.5	.01 (.02)	0	.01 (.02)
210	.15 (.33)	.05 (.12)	.20 (.45)
217.5	.07 (.15)	0	.07 (.15)
225	.20 (.43)	0	0

initial fill - 3.90 kg (8.60 lbs)
final drain - 3.25 kg (7.15 lbs)
change in filter wt. - 0.27 kg (0.59 lbs)
total oil consumed - 1.76 kg (3.87 lb)

TEST 2

Low Blowby Piston Rings

Piston Ring Gap Measurements

End Gap, centimeters (inches)

Piston Ring		Piston No. 1	2	3	4
top ring	before	.058 (.023)	.064 (.025)	.061 (.024)	.061 (.024)
	after	.058 (.023)	.061 (.024)	.058 (.023)	.058 (.023)
	change	0	-.003 (-.001)	-.003 (-.001)	-.003 (-.001)
second ring top	before	.048 (.019)	.058 (.023)	.048 (.019)	.051 (.020)
	after	.038 (.015)	.046 (.018)	.036 (.014)	.043 (.017)
	change	-.010 (-.004)	-.013 (-.005)	-.013 (-.005)	-.008 (-.003)
second ring bottom	before	.048 (.019)	.061 (.024)	.051 (.020)	.056 (.022)
	after	.038 (.015)	.041 (.016)	.038 (.015)	.046 (.018)
	change	-.010 (-.004)	-.020 (-.008)	-.013 (-.005)	-.013 (-.005)

Side Clearance, centimeters (in. x 10^{-3})

Piston Ring		Piston No. 1	2	3	4
top ring	before	.008 (3)	.008 (3)	.008 (3)	.008 (3)
	after	.005 (2)	.005 (2)	.015 (6)	.025 (10)
	change	-.003 (-1)	-.003 (-1)	.008 (3)	.018 (7)
second rings	before	.013 (5)	.010 (4)	.013 (5)	.013 (5)
	after	.015 (6)	.013 (5)	.015 (6)	.015 (6)
	change	.003 (1)	.003 (1)	.003 (1)	.003 (1)

TEST NO. 2
Low Blowby Piston Rings –
Piston and Cylinder Bore Measurements

		Piston No. 1	2	3	4
Cylinder Bore, cm (in.)					
1.1 cm from Top					
Transverse	before	9.8461 (3.8764)	9.8478 (3.8771)	9.8453 (3.8761)	9.8458 (3.8763)
	after	9.8473 (3.8769)	9.8491 (3.8776)	9.8461 (3.8764)	9.8463 (3.8765)
	change	0.0013 (0.0005)	0.0013 (0.0005)	0.0008 (0.0003)	0.0005 (0.0002)
Longitudinal	before	9.8450 (3.8760)	9.8471 (3.8768)	9.8450 (3.8760)	9.8455 (3.8762)
	after	9.8461 (3.8764)	9.8481 (3.8772)	9.8458 (3.8763)	9.8468 (3.8767)
	change	0.0010 (0.0004)	0.0010 (0.0004)	0.0008 (0.0003)	0.0013 (0.0005)
5.87 cm from Top					
Transverse	before	9.8461 (3.8764)	9.8471 (3.8768)	9.8450 (3.8760)	9.8453 (3.8761)
	after	9.8473 (3.8769)	9.8481 (3.8772)	9.8461 (3.8764)	9.8461 (3.8764)
	change	0.0013 (0.0005)	0.0010 (0.0004)	0.0010 (0.0004)	0.0008 (0.0003)
Longitudinal	before	9.8445 (3.8758)	9.8468 (3.8767)	9.8448 (3.8759)	9.8453 (3.8761)
	after	9.8455 (3.8762)	9.8481 (3.8772)	9.8455 (3.8762)	9.8461 (3.8764)
	change	0.0010 (0.0004)	0.0013 (0.0005)	0.0008 (0.0003)	0.0008 (0.0003)
Piston Diameter (T-AT), cm (in.)					
Bottom of oil ring	before	9.8340 (3.8740)	9.8394 (3.8738)	9.8379 (3.8732)	9.8382 (3.8733)
	after	9.8392 (3.8737)	9.8387 (3.8735)	9.8377 (3.8731)	9.8392 (3.8737)
	change	−0.0008 (−0.0003)	−0.0008 (−0.0003)	−0.0002 (−0.0001)	−0.0010 (−0.0004)
Skirt	before	9.8407 (3.8743)	9.8387 (3.8735)	9.8364 (3.8726)	9.8354 (3.8722)
	after	9.8379 (3.8732)	9.8379 (3.8732)	9.8356 (3.8723)	9.8323 (3.8710)
	change	−0.0028 (−0.0011)	−0.0008 (−0.0003)	−0.0008 (−0.0003)	−0.0030 (−0.0012)

due to second groove O-ring, rating not comparible

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE _____
TEST HOURS 225
TEST LABORATORY _____
LUBRICANT REO-203

RATER EL DATE 1-29-75
LABORATORY TEST NUMBER 2
STAND NO. 2 ENGINE NO. 5029085
FUEL AL-5473-G

PISTON NO. 1

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	7.61

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00																		
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100	15	1.5							30	3.0								
	DBrV	0.075	15	1.13							5	.38								
	AV	0.050	20	1.0																
	LAV	0.025																		
	VLAV	0.010	50	.5									10	0.1						
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0	0								65	0	90	0						
ZONAL RATING			4.13								3.38		0.1							
LOCATION FACTOR																				
WEIGHTED RATING																				

*WEIGHTED TOTAL DEPOSITS 7.61

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE _____
TEST HOURS 225
TEST LABORATORY _____
LUBRICANT REO-203

RATER EL DATE 1-29-75
LABORATORY TEST NUMBER 2
STAND NO. 2 ENGINE NO. 5029085
FUEL AL-5473-G

PISTON NO. 2

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	6.55

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1		GROOVES NO. 2		GROOVES NO. 3		GROOVES NO. 4		LANDS NO. 1		LANDS NO. 2		LANDS NO. 3		LANDS NO. 4		UNDER-CROWN	
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00																		
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15	5	0.75																
	CARBON RATING																			
VARNISH	BV	0.100	30	3.0							5	0.5								
	DBrV	0.075	10	.75							10	0.75								
	AV	0.050																		
	LAV	0.025																		
	VLAV	0.010	55	.55																
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0									80	0	100	0						
ZONAL RATING			5.05								1.5									
LOCATION FACTOR																				
WEIGHTED RATING																				

*WEIGHTED TOTAL DEPOSITS 6.55

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE _____
TEST HOURS 225
TEST LABORATORY _____
LUBRICANT REO-203

RATER EL DATE 1-29-75
LABORATORY TEST NUMBER 2
STAND NO. 2 ENGINE NO. 5029085
FUEL AL-5473-G

PISTON NO. 3

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	3.33

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00																		
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15	10	1.5																
	CARBON RATING																			
VARNISH	BV	0.100																		
	DBrV	0.075	5	.38																
	AV	0.050									10	0.5								
	LAV	0.025																		
	VLAV	0.010	85	0.85							10	0.1								
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0									80	0	100	0						
ZONAL RATING			2.73								0.6		0							
LOCATION FACTOR																				
WEIGHTED RATING																				

*WEIGHTED TOTAL DEPOSITS 3.33

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE _____
TEST HOURS 225
TEST LABORATORY _____
LUBRICANT REO-203

RATER EL DATE 1-29-75
LABORATORY TEST NUMBER 2
STAND NO. 2 ENGINE NO. 5029085
FUEL AL-5473-G

PISTON NO. 4

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	19.75

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN	
			NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4			
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00																		
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100	100	10.0							30	3.0	20	2.0						
	DBrV	0.075									10	0.75	5	.38						
	AV	0.050					20	1.0												
	LAV	0.025									60	1.5	25	.62						
	VLAV	0.010											50	0.5						
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0					80	0			0		0		100					
ZONAL RATING			10.0				1.0				5.25		3.5							
LOCATION FACTOR																				
WEIGHTED RATING																				

*WEIGHTED TOTAL DEPOSITS 19.75

Test Number II

RING FACE CONDITION

Engine Model L-141 Serial No. 5029085 Date 1-29-75
Fuel AL-5473-G Lubricant REO-203 Observer ERL

	Cylinder Number					
	1	2	3	4		
First Ring	N	N	N	N		
Second Ring	N	N	N	N		
Third Ring						
Fourth Ring	100	100	100	100		
Oil Ring Slots—% Open						

N-Normal

PISTON SURFACE DEPOSITS

Engine Model L-141 Serial No. 5029085 Date 1-29-75
Fuel AL-5473-G Lubricant REO-203 Observer ERL

		Piston Number					
		1	2	3	4		
Top*		25A,HC 75 Clean	100 1/2A HC	100 1/2A HC	100 1/2A		
Combustion Chamber*		85A, HC 15 Clean	30A, HC 70 Clen	70A, HC 5-8 10-7, 15-0	95A, HC 5-0		
Under Head*		0	0	0	0		
Skirts*	Thrust	0	0	0	5-A 95-0		
	Anti-Thrust	0	0	0	0		
Relief Areas*		0	0	0	0		
Lands demerits	1	25-9 5-6,5-8 65-0	5-9,80-0 10-6 5-5	10-4 10-2 80-0	35-9,25-3 5-7 5-6		
	2	10-2 90-0	100-0	100-0	10-9,25-3 10-8,50-2 5-7		
	3						
	4						

*Carbon and Ash: Use Volume Factor
Indicate H, M, or S

PISTON RING GROOVE DEPOSITS

Engine Model L-141 Serial No. 5029085 Date 1-29-75
Fuel AL-5473-G Lubricant REO-203 Observer ERL

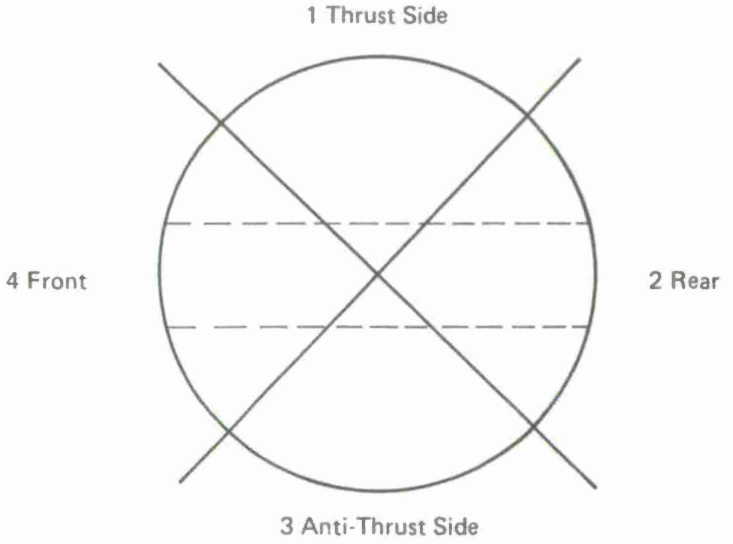
		Cylinder Number											
		1		2		3		4					
		CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN				
Top of Groove*	1	0	2-9 98-0	0	0	0	0	0	0				
	2	0	15-9 15-6 70-0	0	15-8 10-7 70-0	0	10-8 15-7 10-5	0	15-8 30-7 55-0				
	3	0	*	0	*	0	65-0 *	0	0				
	4												
Back of Groove†	1	0	15-9 15-7 50-3 20-5	5-RS 95-0	30-8 10-7 60-2	5-RS 5-A 90-0	5-7 95-2	0	100-9				
	2	0	+	0	+	0	+	0	+				
	3	0	0	0	0	0	0	0	20-5 80-0				
	4												
Bottom of Groove*	1	0	0	0	0	0	0	0	0				
	2	0	0	0	0	0	0	0	0				
	3	0	*	0	*	0	*	0	*				
	4												
Drain Holes—% Blocked													

*Discolored, but does not look like varnish, maybe freating
+Unable to rate because of 0-ring

PISTON GROOVE INSIDE DIAMETER–% RING SUPPORTING CARBON

Engine Model L-141 Serial No. 5029085 Date 1-29-75
Fuel AL-5473-G Lubricant REO-203 Observer ERL

Piston Ring	Quadrant	Piston Number					
		1	2	3	4		
1	1	0	0	0	0		
	2	0	0	0	0		
	3	0	0	0	0		
	4	0	0	0	0		
2	1	0	0	0	0		
	2	0	0	0	0		
	3	0	0	0	0		
	4	0	0	0	0		



PISTON SURFACE CONDITION

Engine Model L-141 Serial No. 5029085 Date 1-29-75
Fuel AL-5473-G Lubricant REO-203 Observer ERL

	Piston Number					
	1	2	3	4		
Top Land	N	N	N	N		
Skirt	N	N	N	N		
Piston Pin	N	N	N	N		

N-Normal

RING STICKING

Engine Model L-141 Serial No. 5029085 Date 1-30-75
Fuel AL-5473-G Lubricant REO-203 Observer ERL

Piston Number

Ring No.	1	2	3	4		
1	F	S	F	F		
2	F	F	F	F		
3	F	F	F	F		
4						

Indicate by letter—Free or Sluggish, or by number and letter—percent Pinched (cold stuck) or percent Hot stuck

RING DEPOSITS

Engine Model L-141 Serial No. 5029085 Date 1-30-75
Fuel AL-5473-G Lubricant REO-203 Observer ERL

Cylinder Number			1		2		3		4					
			CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN				
Piston Ring	Top	1	0	0	0	0	0	10-4 90-0	0	0				
		2	0	0	0	2-5 98-0	0	0	0	0				
		3												
		4												
	ID	1	0	0	0	0	0	0	0	0				
		2	0	0	0	0	0	0	0	0				
		3												
		4												
	Bottom	1	0	0	0	0	0	0	0	0				
		2	0	0	0	0	0	0	0	10-4 90-0				
		3												
		4												

Areas previously rated for carbon, rate 0 for varnish

TEST 3–225 HOURS

STANDARD PISTON RINGS

Fuel: VV-G-001690A (AL-5473)
Lubricant: REO-203
Date Completed: 24 February 1975

TEST 3

Standard Piston Rings
225 hours

Summary of Operating Conditions

2800 RPM MODE	AVG	MIN	MAX
Torque, n-m (ft-lb)	125(92)	117(86)	136(100)
Power, OBS, kilowatts (BHp)	36.7(49.2)	34.1(45.7)	39.7(53.2)
Specific Fuel Cons., kg/kW-hr (lbs/BHp-hr)	.317(.521)	.294(.483)	.347(.571)
Blowby @ 49C (120F), m^3/hr (cu.ft./hr)	1.29(45.6)	.73(25.9)	1.67(58.9)
Sump Temperature, C (F)	122(251)	114(238)	126(259)
Manifold Vacuum, kPa, abs. (in.hg.)	91.6 (2.8)	94.6(1.9)	89.2(3.5)

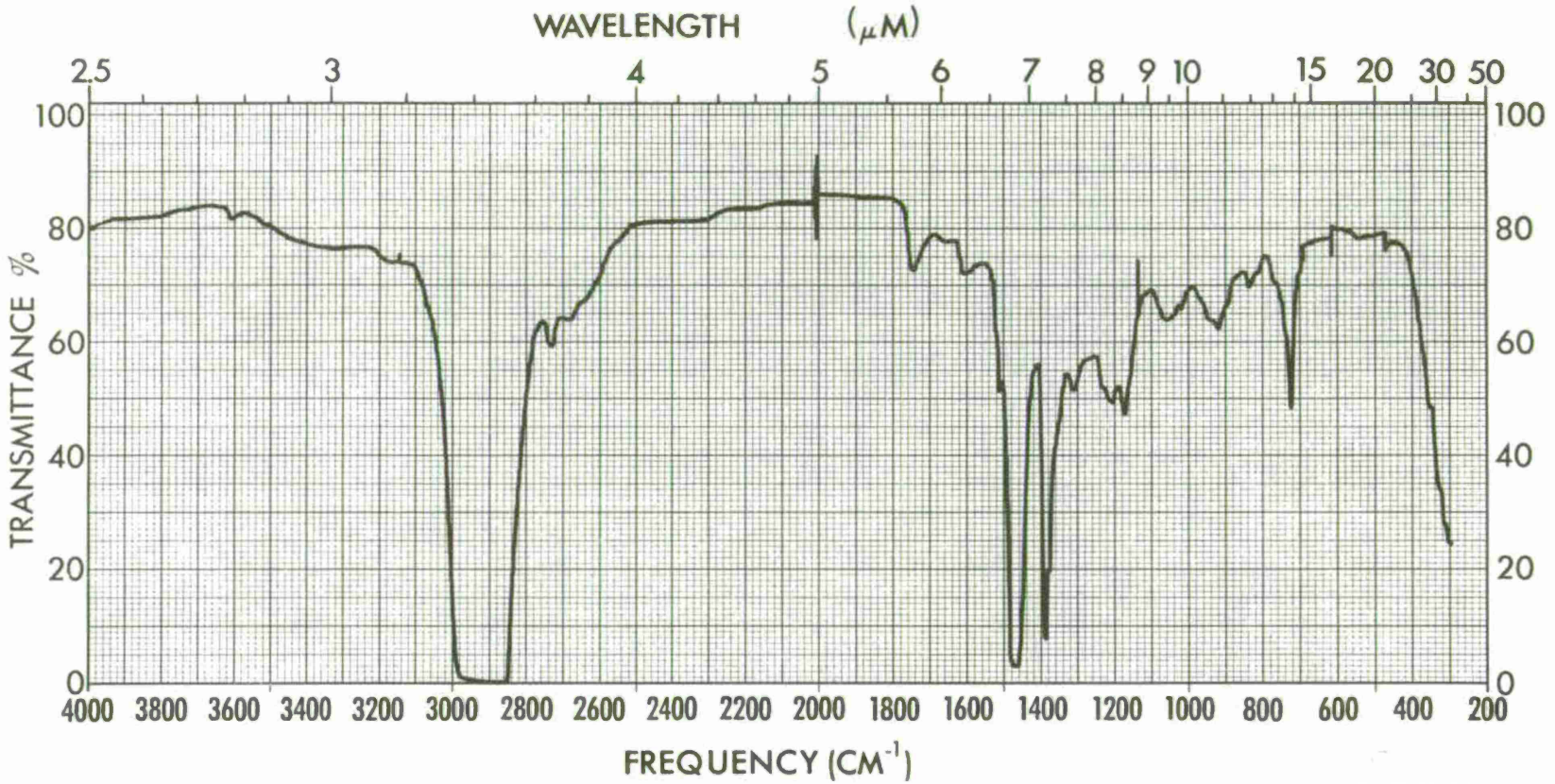
2000 RPM MODE	AVG	MIN	MAX
Torque, n-m (ft-lb)	127(94)	123(91)	130(96)
Power, OBS, kilowatts (BHp)	26.6(35.7)	25.9(34.7)	27.4(36.7)
Specific Fuel Cons., kg/kW-hr (lbs/BHp-hr)	.332(.546)	.284(.467)	.372(.612)
Blowby @ 49C (120F), m^3/hr (cu.ft./hr)	.91(32.1)	.80(28.3)	1.18(41.7)
Sump Temperature, C (F)	104(220)	87(188)	114(238)
Manifold vacuum, kPa, abs. (in. hg.)	91.9(2.7)	96.0(1.5)	90.6(3.1)

600 RPM MODE	AVG	MIN	MAX
Torque, n-m (ft-lb)	0	0	0
Power, OBS, kilowatts (BHp)	0.0	0.0	0.0
Blowby @ 49C (120F), m^3/hr (cu.ft./hr)	0.0	0.0	0.0
Sump Temperature, C (F)	59(138)	50(122)	72(162)
Manifold Vacuum, kPa, abs. (in.hg.)	51.4(14.7)	63.2(11.2)	35.2(19.5)

TEST 3
Standard Piston Rings
225 hours

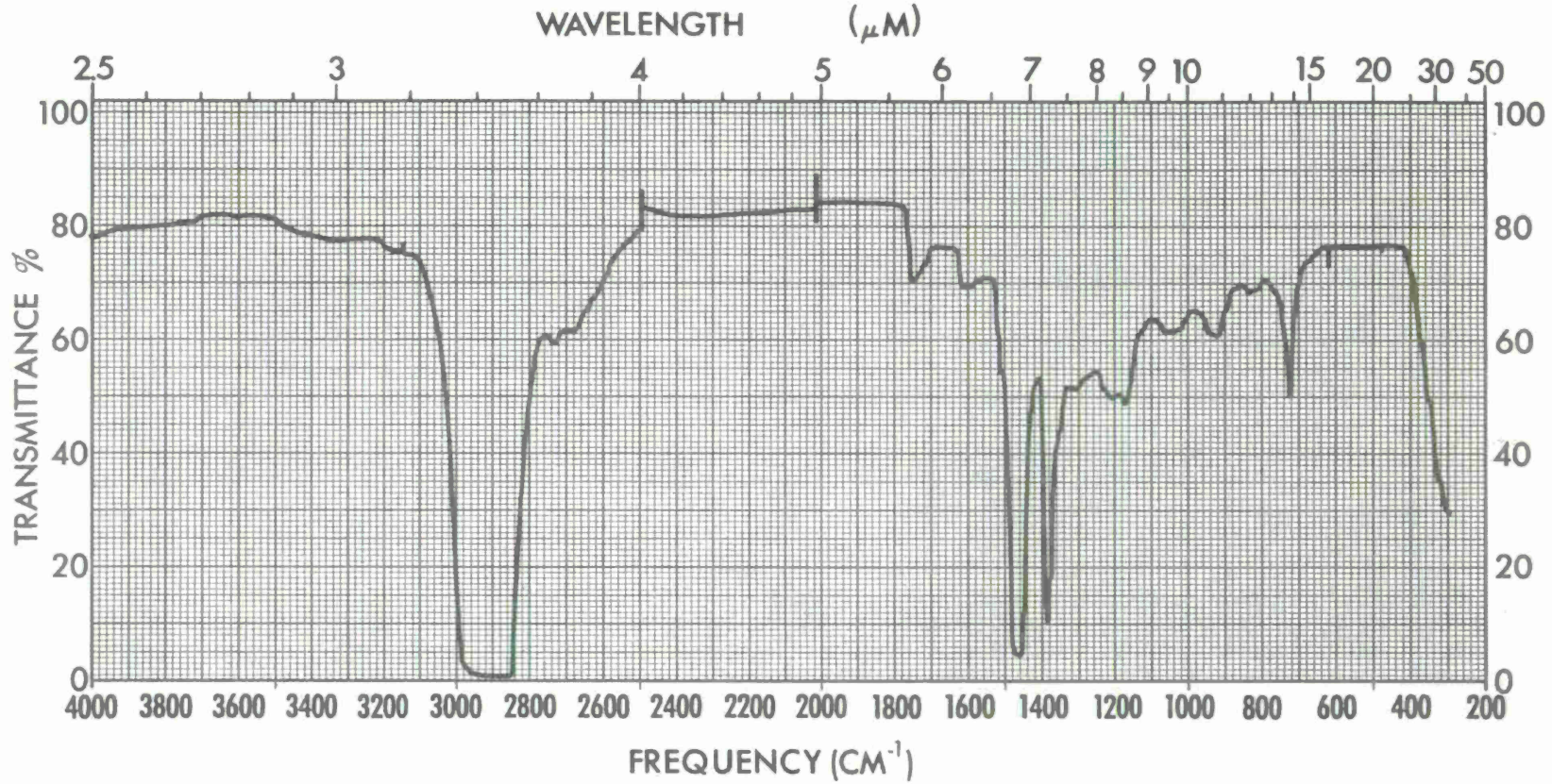
Used Oil Analysis

Test Hour	Viscosity, cS 38°C(100°F)	99°C(210°F)	Total Acid No.	Total Base No.	Insolubles w/coag. Pentane	Benzene
New	121.6	12.61	2.97	5.08	--	--
15	108.66	11.80	2.66	4.96	0.061	0.024
30	107.49	11.63	3.30	4.96	0.036	0.029
45	108.48	N.D.	2.87	4.96	0.031	0.037
60	116.35	12.32	3.30	4.96	0.045	0.053
75	115.75	12.21	3.56	4.50	0.053	0.040
90	117.32	12.41	3.67	4.96	0.062	0.044
105	118.59	12.55	3.40	4.96	0.059	0.046
120	123.07	12.70	3.94	4.04	0.060	0.043
135	128.77	13.10	4.20	4.50	0.084	0.052
150	133.09	N.D.	4.52	N.D.	0.075	0.062
165	136.94	13.72	4.47	3.58	0.076	0.061
180	143.70	14.18	4.86	3.58	0.126	0.068
195	150.89	14.59	5.13	2.66	0.096	0.040
210	156.49	14.88	5.27	2.20	0.105	0.037
225	164.01	15.46	5.39	2.20	0.108	0.054



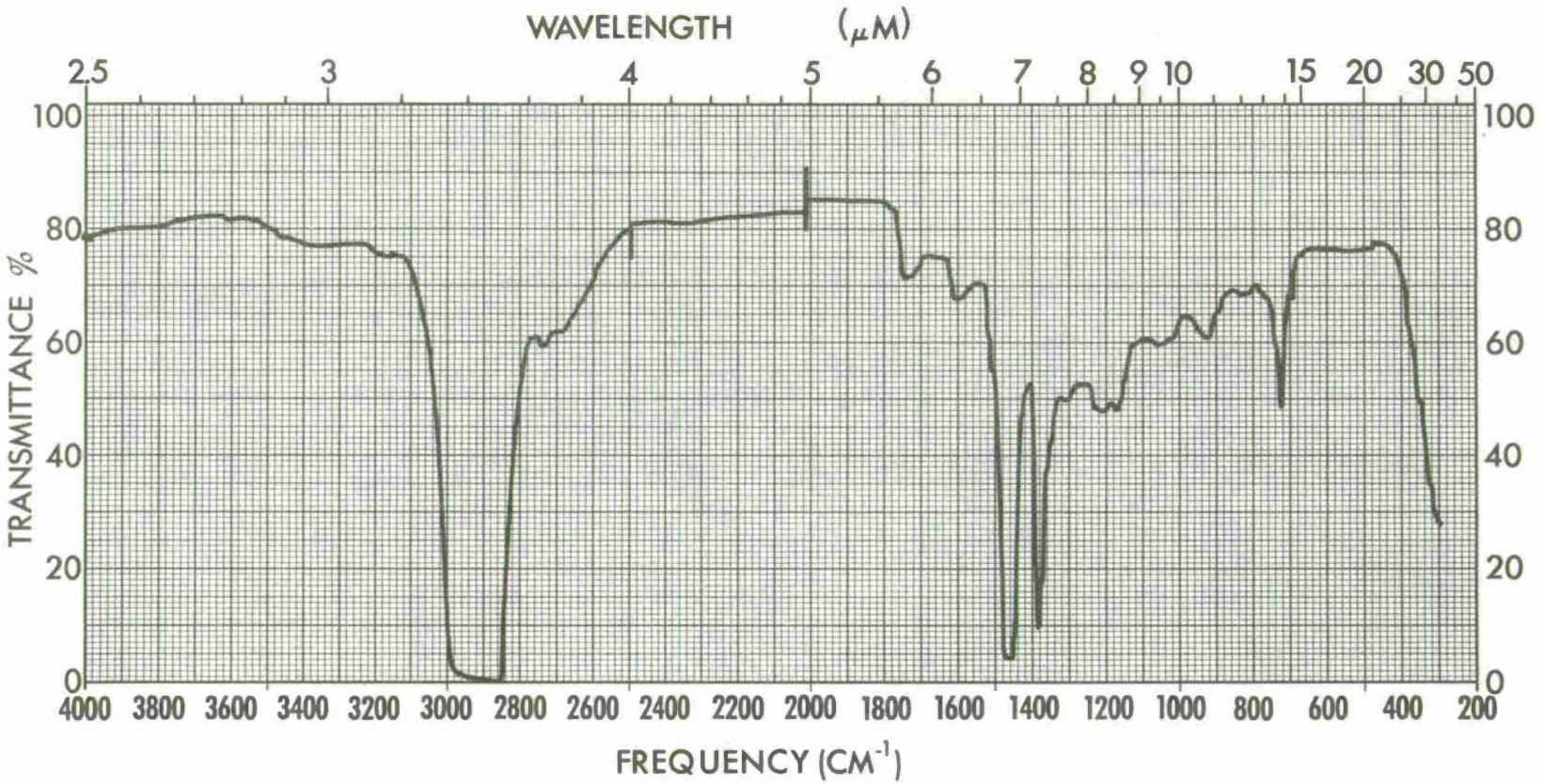
SPECTRUM NO. 569	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
NEW	PURITY	2.	
	PHASE	DATE 12-16-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. SAMPLE



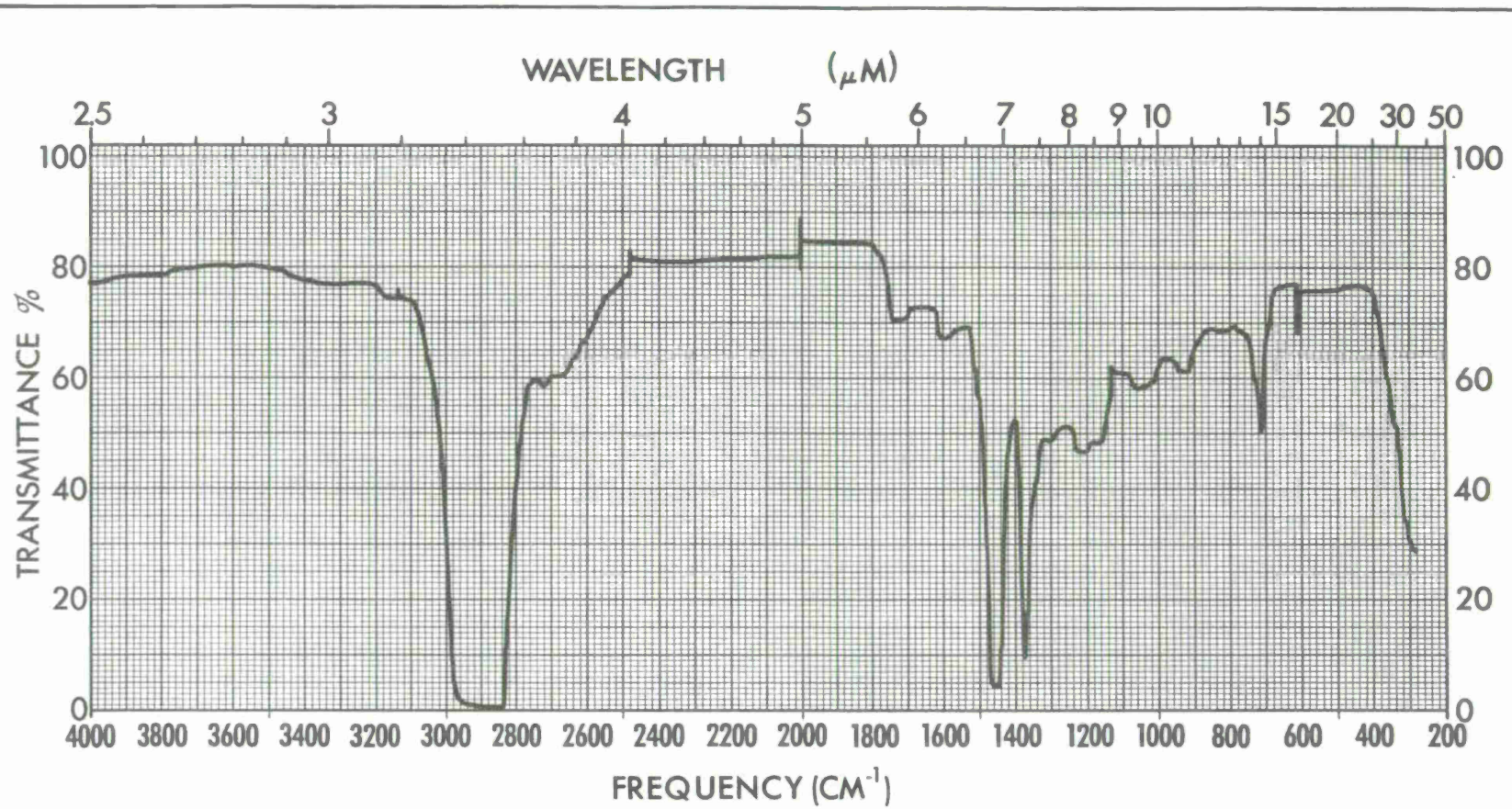
SPECTRUM NO. 607	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
15 HR Test 3	PURITY	2.	
	PHASE	DATE 2-27-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



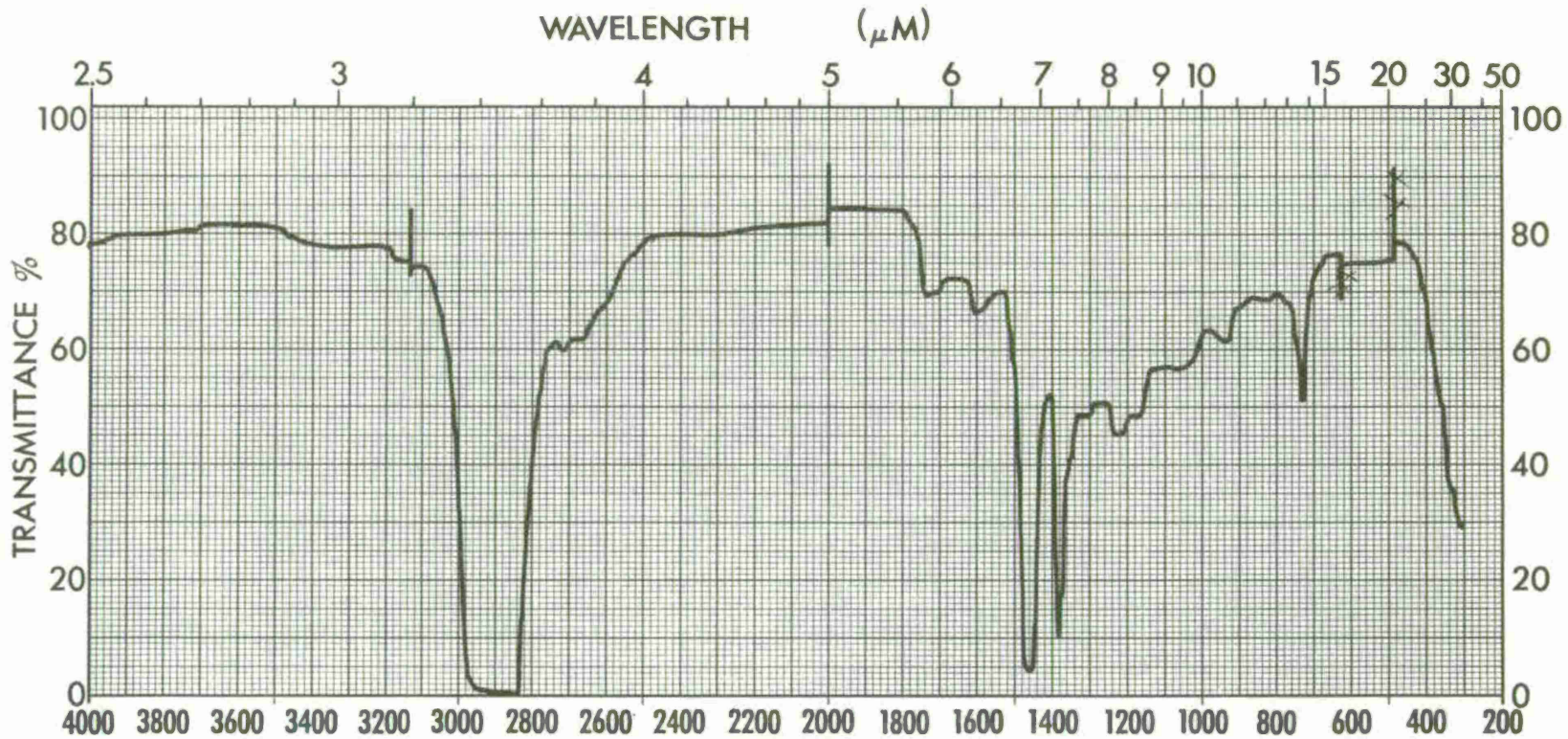
SPECTRUM NO. 608	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
45 HR Test 3	PURITY	2.	
	PHASE	DATE 2-27-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



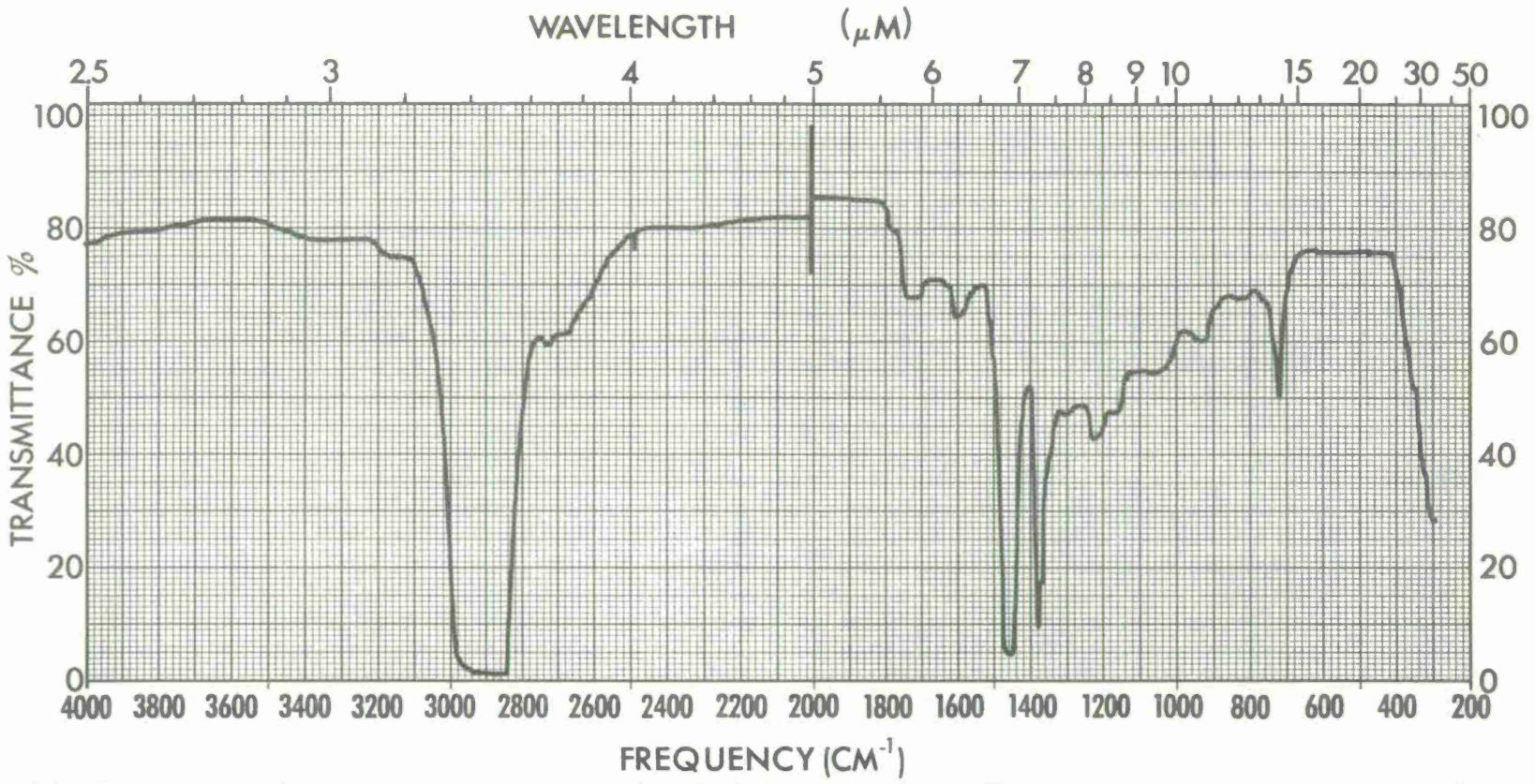
SPECTRUM NO. 609	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
75 HR Test 3	PURITY	2.	
	PHASE	DATE 2-27-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



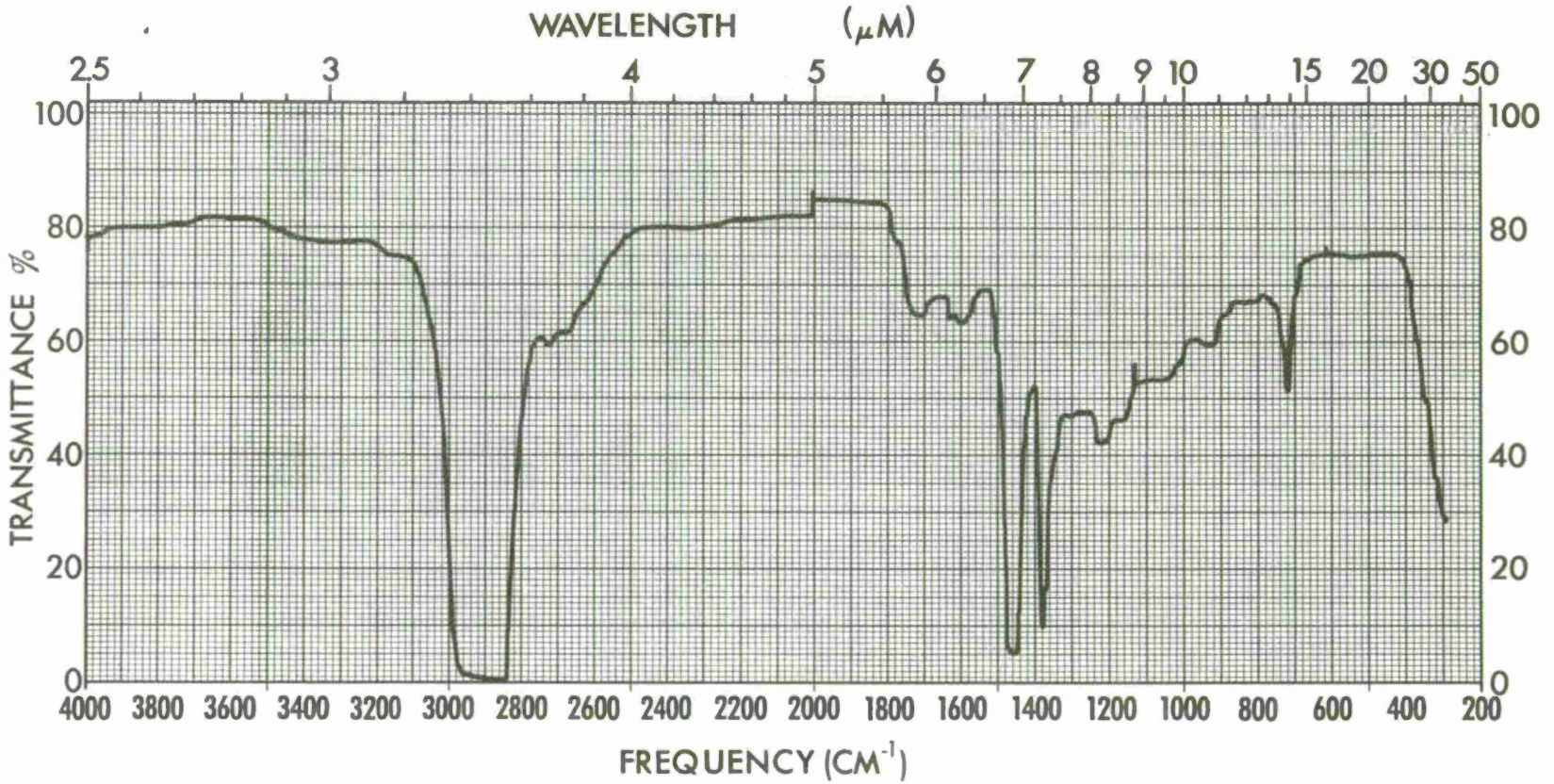
SPECTRUM NO. 610	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
105 HR Test 3	PURITY	2.	
	PHASE	DATE 2-27-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



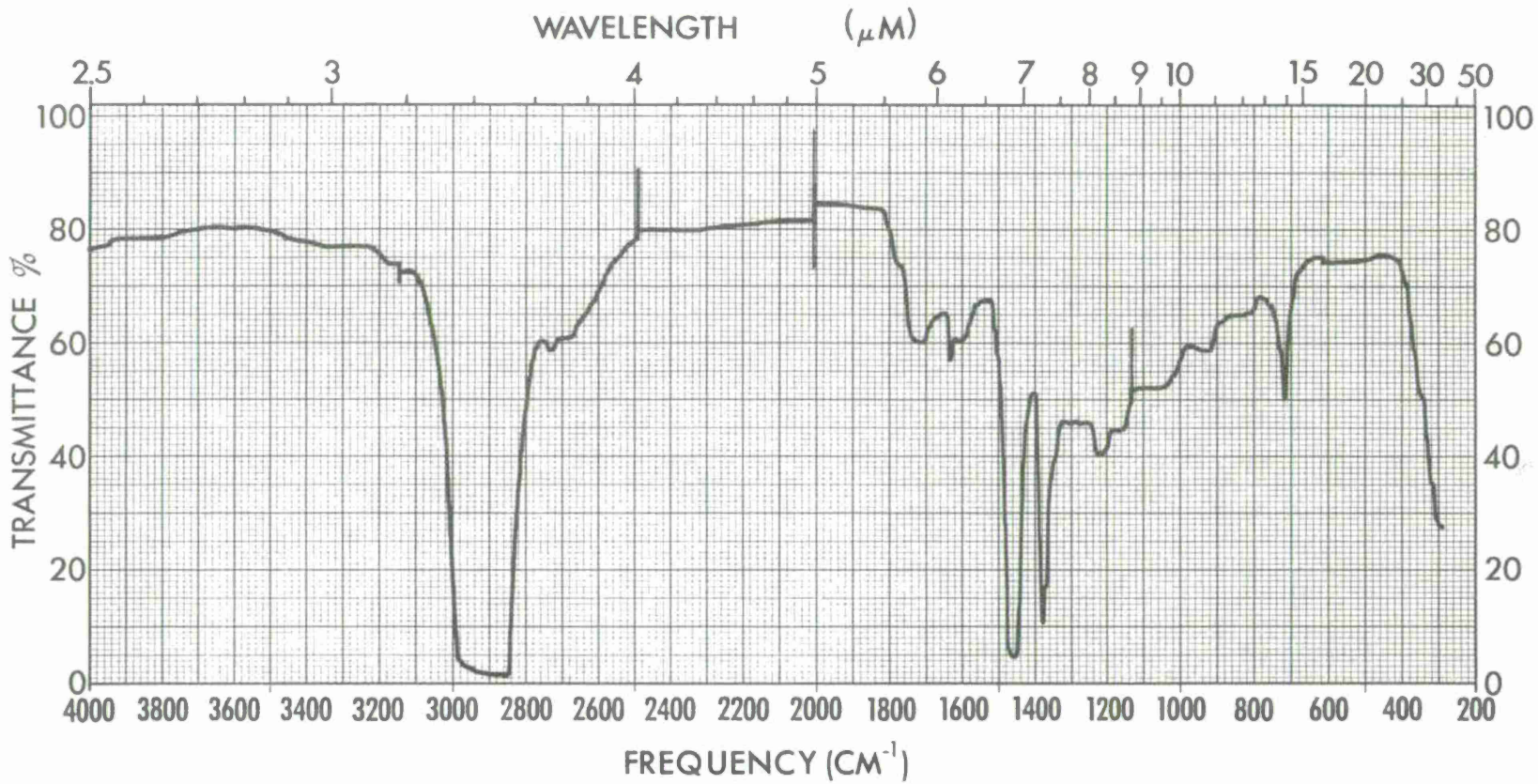
SPECTRUM NO. 611	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
135 HR Test 3	PURITY	2.	
	PHASE	DATE 2-27-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



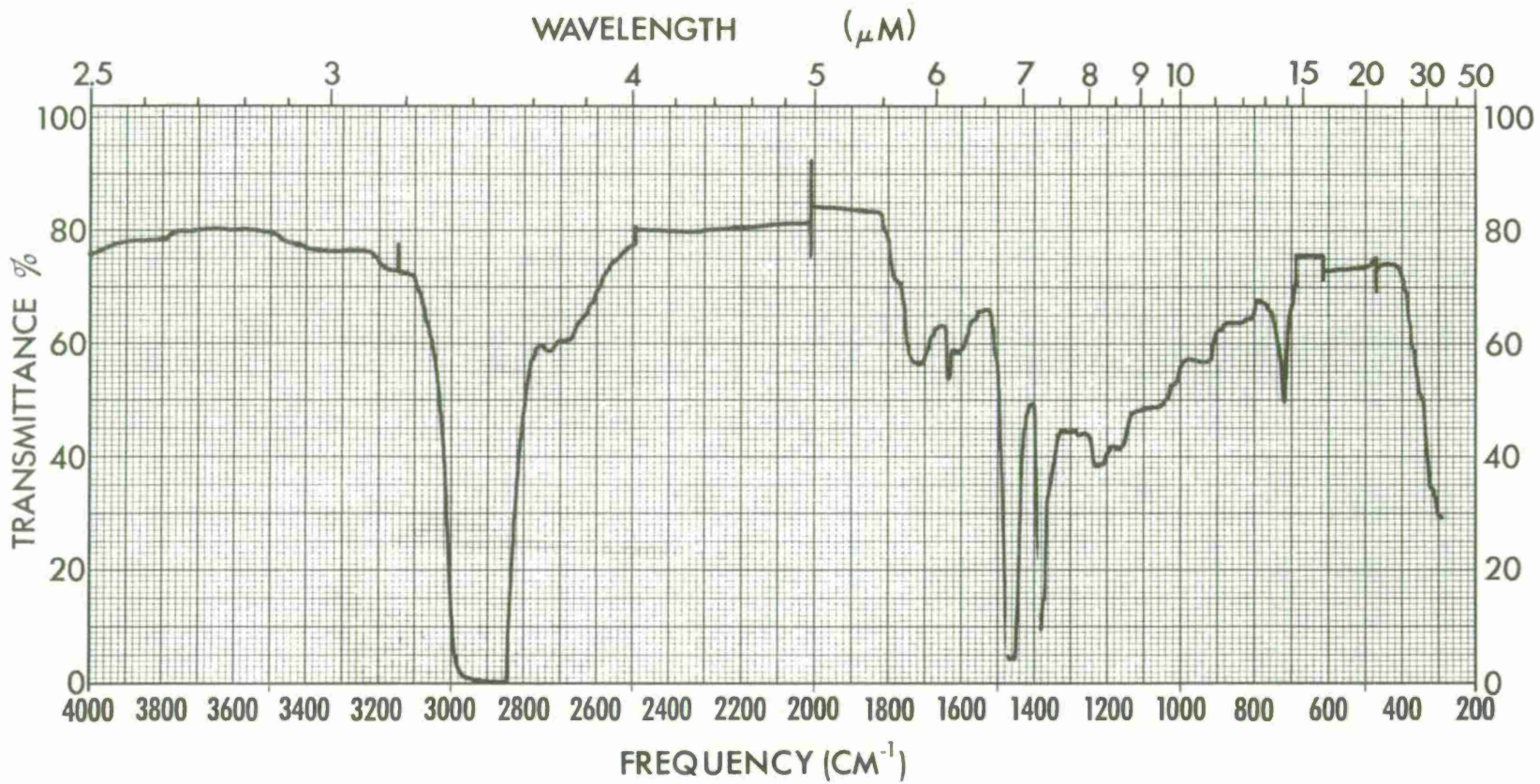
SPECTRUM NO. 612	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
165 HR Test 3	PURITY	2.	
	PHASE	DATE 2-27-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



SPECTRUM NO. 613	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
195 HR Test 3	PURITY	2.	
	PHASE	DATE 2-27-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



SPECTRUM NO. 614	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
225 HR Test 3	PURITY	2.	
	PHASE	DATE 2-29-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. SAMPLE

TEST 3

Standard Piston Rings
225 hours

Oil Consumption

Test Hours	Oil Consumed Kilograms (lbs)	Sample Removed Kilograms (lbs)	Oil Added Kilograms (lbs)
7.5	.10 (.23)	0	.10 (.23)
15	.02 (.05)	.05 (.12)	.08 (.17)
22.5	0	0	0
30	.03 (.07)	.05 (.12)	.09 (.19)
37.5	.10 (.21)	0	.10 (.21)
45	0	.05 (.12)	.05 (.12)
52.5	.09 (.19)	0	.09 (.19)
60	0	.06 (.13)	.06 (.13)
67.5	.09 (.20)	0	.09 (.20)
75	.01 (.01)	.05 (.12)	.06 (.13)
82.5	.07 (.16)	0	.07 (.16)
90	.04 (.09)	.05 (.12)	.10 (.21)
97.5	0	0	0
105	0	.05 (.12)	.05 (.12)
112.5	0	0	0
120	.09 (.19)	.05 (.12)	.14 (.31)
127.5	.06 (.13)	0	.06 (.13)
135	0	.05 (.12)	.05 (.12)
142.5	.12 (.26)	0	.12 (.26)
150	.01 (.03)	.05 (.12)	.07 (.15)
157.5	0	0	0
165	0	.05 (.12)	.05 (.12)
172.5	0	0	0
180	.11 (.25)	.05 (.12)	.17 (.37)
187.5	.04 (.08)	0	.04 (.08)
195	.11 (.25)	.05 (.12)	.17 (.37)
202.5	0	0	0
210	0	.05 (.12)	.05 (.12)
217.5	0	0	0
225	.07 (.15)	0	0

initial fill - 3.90 kg (8.59 lb)
final drain - 2.74 kg (6.03 lb)
change in filter wt - 0.28 kg (0.62 lb)
total oil consumed - 2.04 kg (4.49 lb)

TEST 3

Standard Piston Rings
225 hours

Piston Ring Gap Measurements

End Gap, centimeters (inches)

Piston Ring		Piston No. 1	2	3	4
top ring	before	.059(.023)	.061(.024)	.061(.024)	.064(.025)
	after	.056(.022)	.053(.021)	.056(.022)	.053(.021)
	change	-.003(-.001)	-.008(-.003)	-.050(-.002)	-.010(-.004)
second ring	before	.058(.023)	.074(.029)	.058(.023)	.066(.026)
	after	.061(.024)	.064(.025)	.058(.023)	.061(.024)
	change	.003(.001)	-.010(-.004)	0	-.005(-.002)

Side Clearance, centimeters (inch x 10^{-3})

Piston Ring		Piston No. 1	2	3	4
top ring	before	.008(3)	.010(4)	.008(3)	.008(3)
	after	.005(2)	.005(2)	.005(2)	.005(2)
	change	-.003(-1)	-.005(-2)	-.003(-1)	-.003(-1)
second ring	before	.008(3)	.010(4)	.005(2)	.010(4)
	after	.005(2)	.005(2)	.005(2)	.005(2)
	change	-.003(-1)	-.005(-2)	0	-.005(-2)

Piston and Cylinder Bore Measurements

		Piston No. 1	2	3	4
Cylinder Bore, cm (in.)					
1.11 cm from Top					
Transverse	before	9.8473 (3.8769)	9.8491 (3.8776)	9.8463 (3.8765)	9.8463 (3.8765)
	after	9.8461 (3.8764)	9.8483 (3.8773)	9.8455 (3.8762)	9.8453 (3.8761)
	change	−0.0013 (−0.0005)	−0.0008 (−0.0003)	−0.0008 (−0.0003)	−0.0010 (−0.0004)
Longitudinal	before	9.8461 (3.8764)	9.8481 (3.8772)	9.8458 (3.8763)	9.8468 (3.8767)
	after	9.8455 (3.8762)	9.8481 (3.8772)	9.8450 (3.8760)	9.8455 (3.8762)
	change	−0.0005 (−0.0002)	0	−0.0008 (−0.0003)	−0.0013 (−0.0005)
5.87 cm from Top					
Transverse	before	9.8473 (3.8769)	9.8481 (3.8772)	9.8461 (3.8764)	9.8461 (3.8764)
	after	9.8463 (3.8765)	9.8473 (3.8769)	9.8453 (3.8761)	9.8453 (3.8761)
	change	−0.0010 (−0.0004)	−0.0008 (−0.0003)	−0.0008 (−0.0003)	−0.0008 (−0.0003)
Longitudinal	before	9.8455 (3.8762)	9.8481 (3.8772)	9.8455 (3.8762)	9.8461 (3.8764)
	after	9.8445 (3.8758)	9.8471 (3.8768)	9.8448 (3.8759)	9.8453 (3.8761)
	change	−0.0010 (−0.0004)	−0.0010 (−0.0004)	−0.0008 (−0.0003)	−0.0008 (−0.0003)
Piston Diameter, cm (in.)					
Bottom of oil ring	before	9.8379 (3.8732)	9.8379 (3.8732)	9.8400 (3.8740)	9.8377 (3.8731)
	after	9.8369 (3.8728)	9.8389 (3.8736)	9.8394 (3.8738)	9.8384 (3.8734)
	change	−0.0010 (−0.0004)	0.0010 (0.0004)	−0.0005 (−0.0002)	0.0008 (0.0003)
Skirt	before	9.8384 (3.8734)	9.8405 (3.8742)	9.8379 (3.8732)	9.8372 (3.8729)
	after	9.8384 (3.8734)	9.8415 (3.8746)	9.8394 (3.8738)	9.8369 (3.8728)
	change	0	0.0010 (0.0004)	0.0015 (0.0006)	−0.0003 (−0.0001)

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE _____
TEST HOURS 225
TEST LABORATORY _____
LUBRICANT REO-203

RATER ERL DATE 2-26-75
LABORATORY TEST NUMBER 3
STAND NO. 2 ENGINE NO. 5029083
FUEL AL-5473-G

PISTON NO. 1

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	15

Average = 20.5

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00																		
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100											25	2.5						
	DBrV	0.075																		
	AV	0.050	85	4.25	100	5.0					40	2.0	25	1.25						
	LAV	0.025																		
	VLAV	0.010																		
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0					100	0			60	0	50	0	100	0			100	0
ZONAL RATING			4.25		5.0		0		0		2.0		3.75							
LOCATION FACTOR																				
WEIGHTED RATING																				

*WEIGHTED TOTAL DEPOSITS

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE _____
TEST HOURS 225
TEST LABORATORY _____
LUBRICANT REO-203

RATER ERL DATE 2-26-75
LABORATORY TEST NUMBER 3
STAND NO. 2 ENGINE NO. 5029083
FUEL AL-5473-G

PISTON NO. 2

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	24.5

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1		GROOVES NO. 2		GROOVES NO. 3		GROOVES NO. 4		LANDS NO. 1		LANDS NO. 2		LANDS NO. 3		LANDS NO. 4		UNDER-CROWN	
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00	5	5																
	MHC	0.75																		
	MC	0.50	5	2.5																
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100									30	3.0	30	3.0						
	DBrV	0.075																		
	AV	0.050	90	4.5	100	5.0					10	0.5	20	1.0						
	LAV	0.025																		
	VLAV	0.010																		
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0	0		0		100	0			60	0	50	0	100	0				
ZONAL RATING			12.0		5.0		0		0		3.5		4.0		0					
LOCATION FACTOR																				
WEIGHTED RATING																				

*WEIGHTED TOTAL DEPOSITS

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE _____
TEST HOURS 225
TEST LABORATORY _____
LUBRICANT REO-203

RATER ERL DATE 2-26-75
LABORATORY TEST NUMBER 3
STAND NO. 2 ENGINE NO. 5029083
FUEL AL-5473-9

PISTON NO. 3

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	22.5

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN	
			NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4			
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00	10	10																
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100									15	1.5	15	1.5						
	DBrV	0.075									10	.75	10	.75						
	AV	0.050	60	3.0	100	5.0														
	LAV	0.025																		
	VLAV	0.010																		
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0	30	0	0		100				75	0	75	0	100					
ZONAL RATING			13.0		5.0		0				2.25		2.25							
LOCATION FACTOR																				
WEIGHTED RATING																				

*WEIGHTED TOTAL DEPOSITS

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE _____
TEST HOURS 225
TEST LABORATORY _____
LUBRICANT REO-203

RATER ERL DATE 2-26-75
LABORATORY TEST NUMBER 3
STAND NO. 2 ENGINE NO. 5029083
FUEL AL-5473-G

PISTON NO. 4

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	20.0

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN	
			NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4			
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00	10	10																
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100									20	2.0								
	DBrV	0.075									10	.75								
	AV	0.050	30	1.5	100	5.0					15	.75								
	LAV	0.025																		
	VLAV	0.010																		
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0	60	0	0		100	0												
ZONAL RATING			11.5		5.0						3.5									
LOCATION FACTOR																				
WEIGHTED RATING																				

*WEIGHTED TOTAL DEPOSITS

RING STICKING

Engine Model L-141 Serial No. 5029083 Date 2-26-75
Fuel AL-5473-6 Lubricant REO-203 Observer EL

225 hour - standard eng.

Ring No.	Piston Number 1	2	3	4		
1	F	F	F	F		
2	F	F	F	F		
3	F	F	F	F		
4						

Indicate by letter—Free or Sluggish, or by number and letter—percent Pinched (cold stuck) or percent Hot stuck.

RING DEPOSITS

Engine Model L-141 Serial No. 5029083 Date 2-56-75
Fuel AL-5473-G Lubricant REO-203 Observer EL

Cylinder Number			1		2		3		4					
			CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN				
Piston Ring	Top	1	0	0	0	20	0	0	0	10				
		2	0	0	0	0	0	40	0	10				
		3												
		4												
	ID	1	15	85	0	100	0	100	0	100				
		2	0	100	0	100	0	100	0	100				
		3												
		4												
	Bottom	1	0	30	0	40	0	10	0	20				
		2	0	60	0	80	0	90	0	85				
		3												
		4												

Areas previously rated for carbon, rate 0 for varnish

RING FACE CONDITION

Engine Model L-141 Serial No. 5029083 Date 2-26-75
Fuel AL-5473-G Lubricant REO-203 Observer EL

	Cylinder Number					
	1	2	3	4		
First Ring	N	N	N	N		
Second Ring	N	N	N	N		
Third Ring						
Fourth Ring						
Oil Ring Slots—% Open	100	100	100	100		

N - Normal

PISTON SURFACE DEPOSITS

Engine Model L-141 Serial No. 5029083 Date 2-26-75
Fuel AL-5473-G Lubricant REO-230 Observer EL

		Piston Number					
		1	2	3	4		
Top*		100% 1/2AH	100% 1/2AH	100% 1/2AH	100% 1/2 AH		
Combustion Chamber*		20%AH	10AH	10AH	15AH		
Under Head*		0	0	0	0		
Skirts*	Thrust	0	0	0	0		
	Anti-Thrust	0	0	0	0		
Relief Areas*		0	0	0	0		
Lands demerit	1	25-4 15-5	30-9 10-5	15-9 10-6	20-9 10-7,15-5		
	2	25-8 15-5 10-4	30-9 20-5	15-9 10-6	15-9 10-6,15-5		
	3	0	0	0	0		
	4						

*Carbon and Ash: Use Volume Factor
Indicate H, M, or S

PISTON RING GROOVE DEPOSITS

Engine Model L-141 Serial No. 5029083 Date 2-26-75
Fuel AL-5473-G Lubricant REO-203 Observer EL

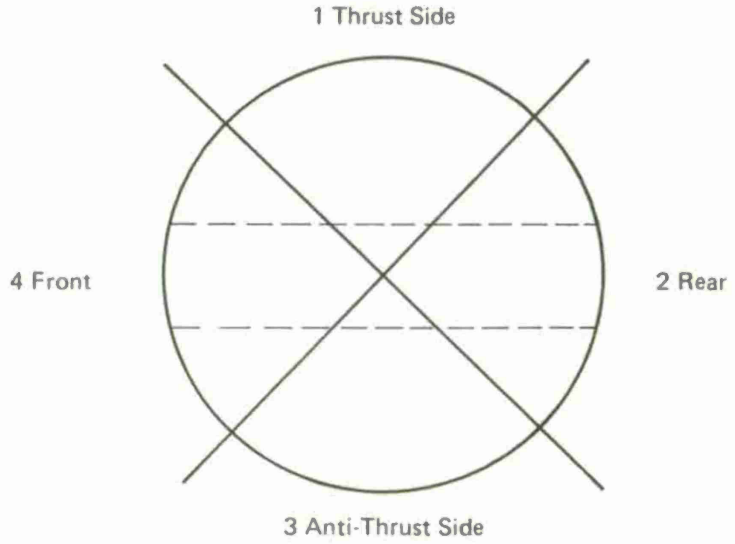
		Cylinder Number											
		1		2		3		4					
		CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN				
Top of Groove*	1	0	50	0	20	0	10	0	25				
	2	0	0	0	0	0	20	0	15				
	3	0	0	0	0	0	5	0	0				
	4												
Back of Groove†	1	15	85	10	90	10	60	10	30				
	2	0	100	0	100	0	100	0	100				
	3	0	0	0	0	0	0	0	0				
	4												
Bottom of Groove*	1	0	0	0	0	0	10	0	0				
	2	0	0	0	0	0	0	0	0				
	3	0	0	0	0	0	0	0	0				
	4												
Drain Holes—% Blocked													

*Carbon and Ash: Use Volume Factor
Indicate H, M, or S
†Carbon and Ash: Indicate Percent Filled and H, M, or S

PISTON GROOVE INSIDE DIAMETER–% RING SUPPORTING CARBON

Engine Model L-141 Serial No. 5029083 Date 2-26-75
Fuel AL-5473-G Lubricant RO-203 Observer EL

Piston Ring	Quadrant	Piston Number					
		1	2	3	4		
1	1	0	5	0	0		
	2	0	0	0	0		
	3	0	0	5	10		
	4	0	0	5	0		
2	1	0	0	0	0		
	2	0	0	0	0		
	3	0	0	0	0		
	4	0	0	0	0		



PISTON SURFACE CONDITION

Engine Model L-141 Serial No. 5029083 Date 2-26-75
Fuel AL-5473-G Lubricant REO-203 Observer EL

	Piston Number					
	1	2	3	4		
Top Land	N	N	N	N		
Skirt	N	N	N	N		
Piston Pin	N	N	N	N		

N-Normal

APPENDIX E

ROAD TEST COURSE

Appendix E
Road Test Course

The road evaluation of the two M-151 vehicles was conducted on and around the grounds of Southwest Research Institute in San Antonio, Texas from 1 April through 27 April 1975. A map of the 45.5-km (28.3-mile) course is given as Figure E-1, and a plot of the minimum and maximum temperatures, the daily rainfall and the actual days of vehicle operation for the test are given in Figure E-2. The test course contained a variety of operating conditions ranging from interstate highway to unimproved dirt road. The highway portion of the route consisted of 8.2 km (5.1 miles) of four-lane highway with a maximum speed limit of 88 km/hr (55 mile/hr). Forty-eight percent of the course, or 21.8 km (13.6 miles) consisted of urban or post-type operation with an average of eight complete stops and two traffic lights per circuit. The speed limits for this phase varied from 32 km/hr (20 mile/hr) to as high as 64 km/hr (40 mile/hr), but the average speed limit was approximately 48 km/hr (30 mile/hr).

The unimproved portion of the course was 15.5 km (9.6 miles) of hardpacked dirt. However, during two periods of heavy rains, this section became impassable and was omitted. These periods are denoted by the dotted portions of the actual operating days section of Figure E-2.

The two vehicles were driven 14 hr/day, five days per week according to the schedule given in Table E-1, and they accumulated mileage at the rate of approximately 640 km (400 miles) per day. The vehicles were inspected and refueled daily, and the vehicles switched the lead each day. Table E-2 is the service schedule for the two vehicles.

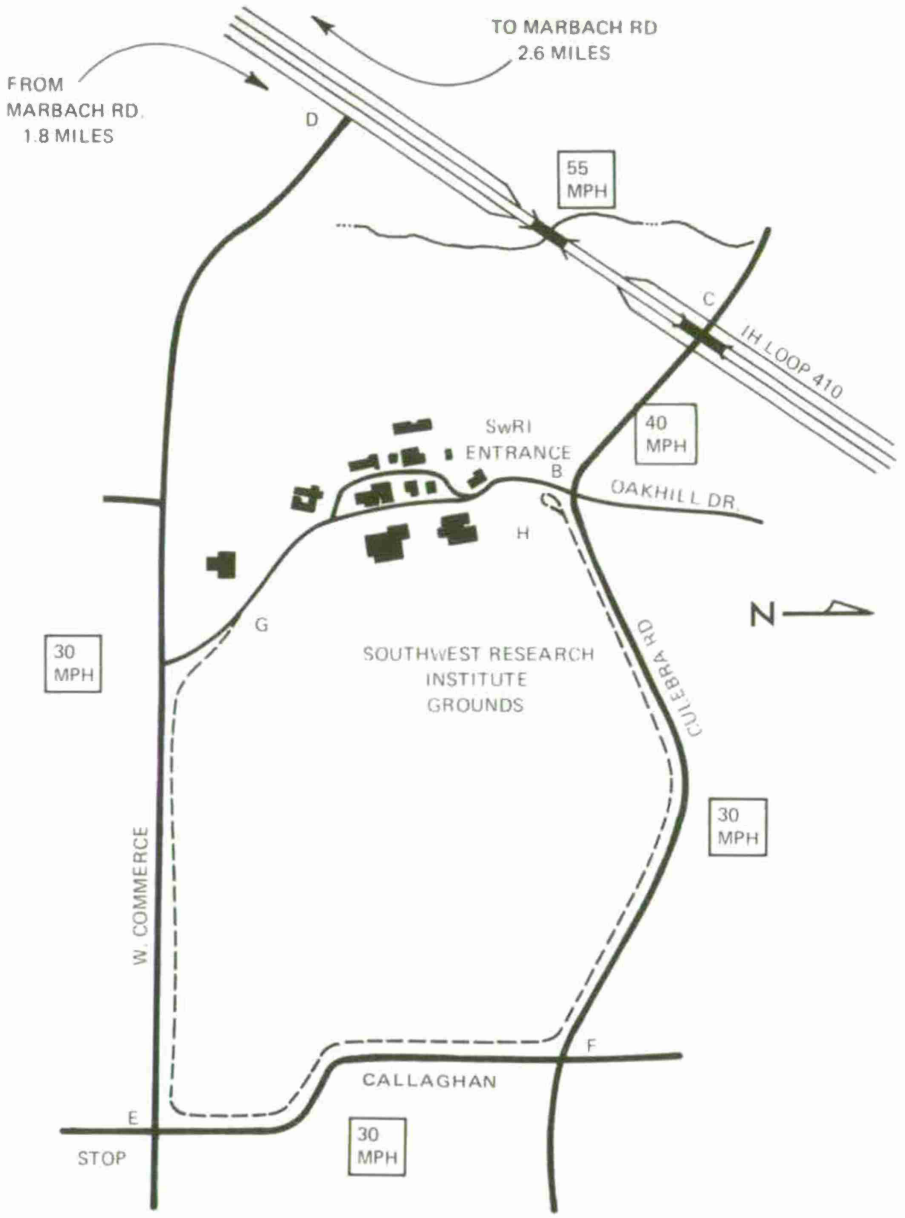
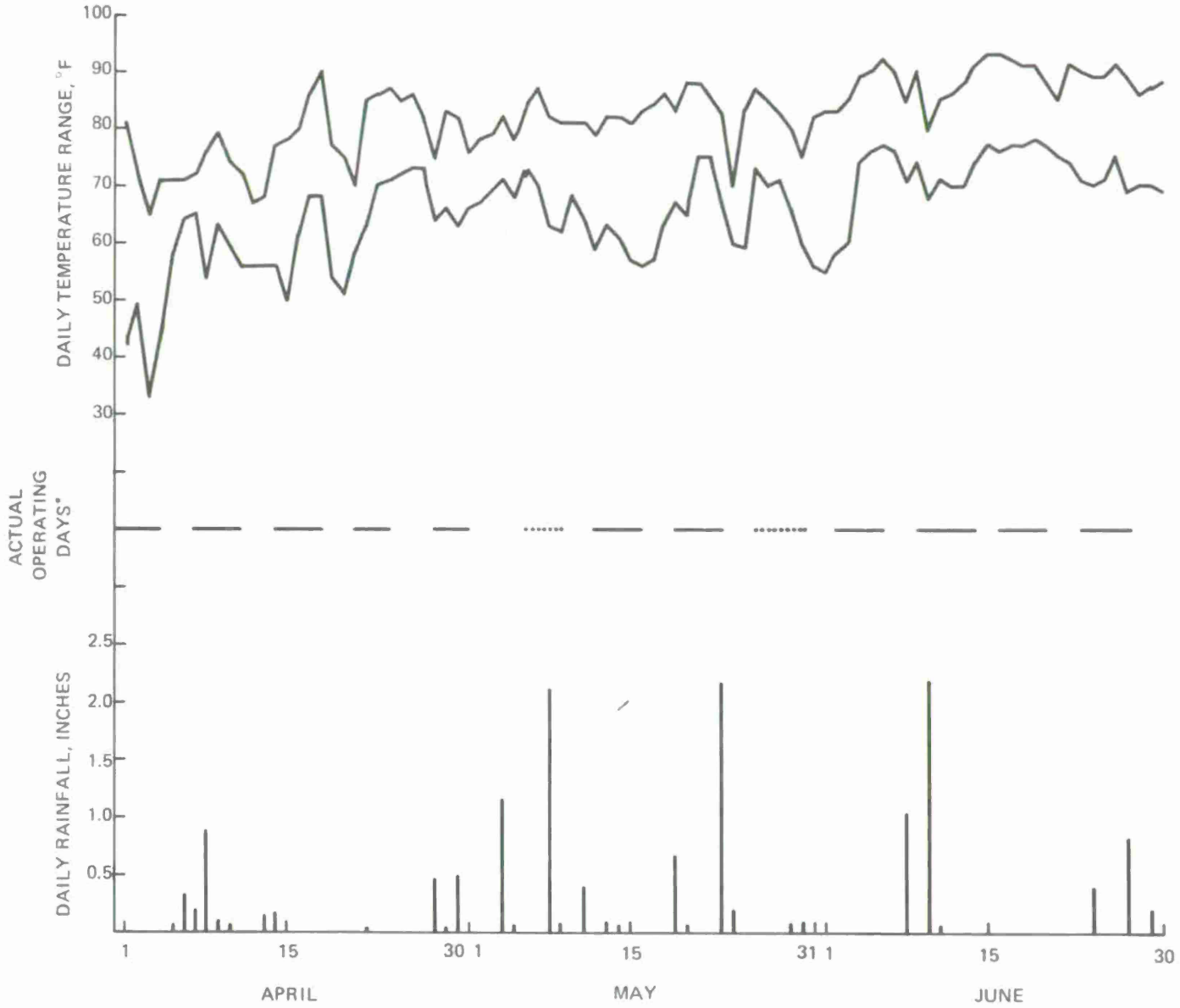


FIGURE E-1. M-151 ROAD TEST COURSE

TABLE E-1. TEST DRIVER INSTRUCTIONS

Step	Present Position	Instruction	Speed Limit, mph
1	A	Drive to main gate (B)	25
2	B	Left on Culebra Rd. to IH-410 (C)	40
3	C	Left onto IH-410 to Marbach Rd.–exit	55
4	-	Left on Marbach Rd., then left to IH-410	
5	-	IH-410 to W. Commerce (D)–exit	55
6	D	Right on W. Commerce to Callaghan Rd. (E)	30
7	E	Left on Callaghan Rd. to Culebra (F)	30
8	F	Left on Culebra to main gate (B)	30
9	B	Left into Institute to dirt road (G)	25
10	G	Follow dirt road to turnaround (H)	20
11	H	Return along dirt road to roadway (G)	20
12	G	Drive to main gate (B)	25
13	B	Right on Culebra to Callaghan Rd. (F)	30
14	F	Right on Callaghan to W. Commerce (E)	30
15	E	Right on W. Commerce to IH-410 (D)	30
16	D	Right on IH-410 to Culebra (C)–exit	55
17	C	Right on Culebra to main gate (B)	40
18	B	Right into Institute to dirt road (G)	25
19	G	Follow dirt road to turnaround (H)	20
20	H	Return along dirt road to roadway (G)	20

This completes one lap; return to Step 1 and repeat.



*DOTTED LINES DENOTE DAYS WHEN DIRT SECTIONS OF COURSE IMPASSABLE DUE TO HEAVY RAINS.

FIGURE E-2. ROAD EVALUATION DATA

TABLE E-2

M-151 Maintenance and Oil Sampling Schedule

Test Distance Kilometers (miles)	Operation
4,800 (3,000)	Take 25ml sample of engine oil
9,650 (6,000)	Take 25ml sample of engine oil
12,800 (8,000)	Tune up engine (clean & set points, plugs), grease, general checkup, etc. Take 25ml sample of transmission and differential lubes Determine road octane requirement
14,500 (9,000)	Take 25ml sample of engine oil
19,300 (12,000)	Take 75ml sample of engine oil
24,100 (15,000)	Take 25ml sample of engine oil
25,700 (16,000)	Tune up engine (replace points, plugs), grease, general checkup, etc. Take 25ml sample of transmission and differential lubes Determine road octane requirement
28,900 (18,000)	Take 25ml sample of engine oil
33,800 (21,000)	Take 75ml sample of engine oil
End of Test	Take 75ml sample of engine, transmission, and differential lubes Tune up engine (replace points, plugs), grease, general checkup, etc. Determine road octane requirement

APPENDIX F

M-151 ROAD TEST RESULTS

M-151 ROAD TEST RESULTS

STANDARD PISTON RINGS

Fuel:	AL-5894-G Unleaded
Lubricant:	REO-203
Total Distance:	35,661 Kilometers (22,164 miles)
Date Completed:	27 June 1975

35,560 Kilometer Road Test - M151 Vehicle
Standard Piston Rings

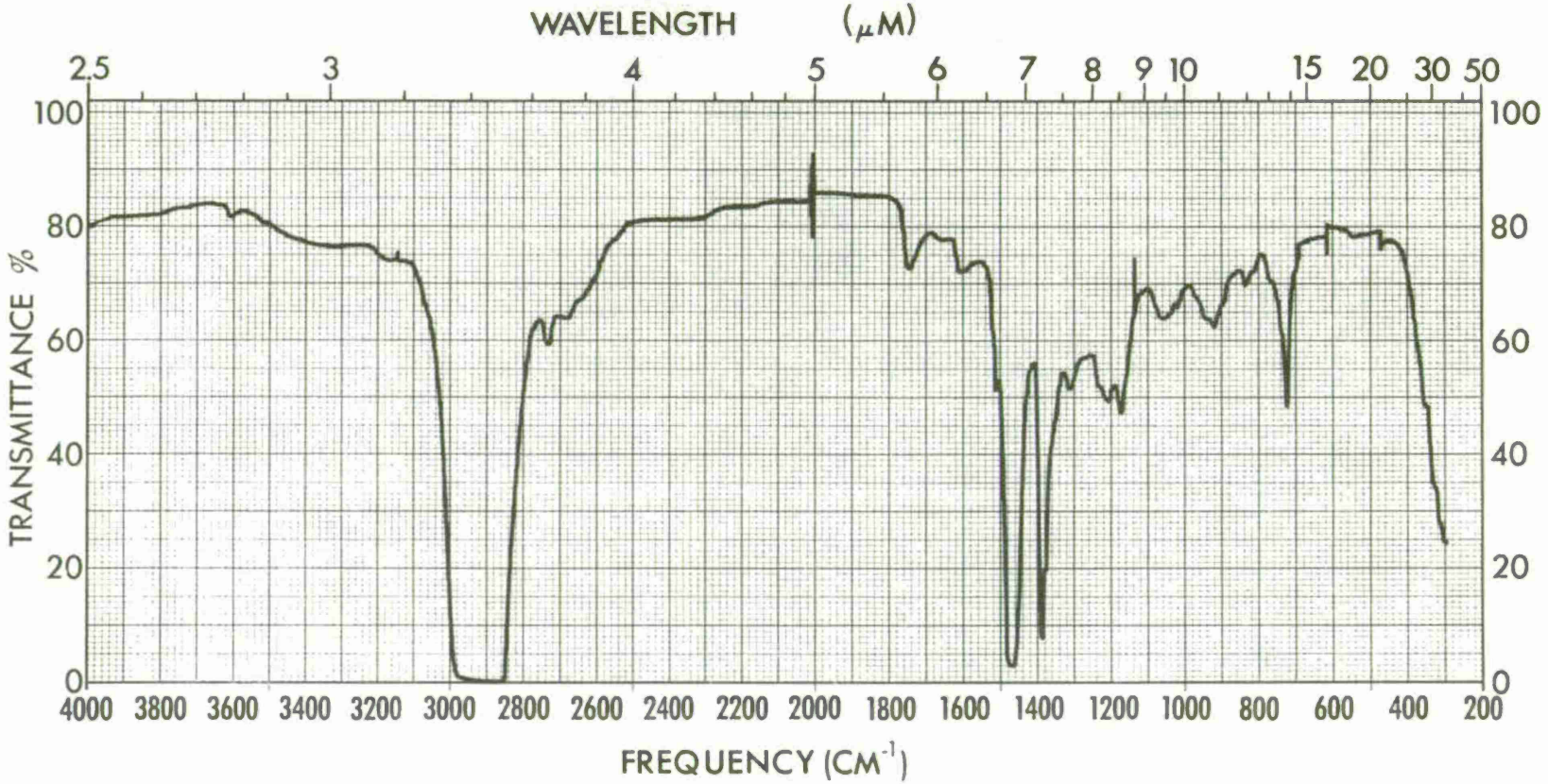
Used Oil Analysis

Test Distance Kilometers(miles)	Viscosity, cS 38°C(100°F)	99°C(210°F)	TAN	TBN	Metals by AA, ppm Fe	Cu	Pb	Insolubles Pentane	Benzene
New	121.6	12.61	2.97	5.08	--	--	--	--	--
4,830 (3,000)	115.40	12.29	3.33	4.50	59	23	N.D.		
9,294 (5,776)	121.93	12.77	3.53	4.50	92	21	N.D.		
14,480 (9,000)	140.01	14.01	4.46	3.64	211	49	359		
19,717 (12,254)	153.5	14.93	4.77	3.19	244	61	320	1.59	0.51
23,741 (14,755)	175.03	17.87	4.01	3.41	323	130	448		
29,273 (18,193)	181.35	16.90	6.65	3.70	306	82	454		
34,359 (21,354)	227.28	19.51	7.33	1.84	377	96	488		
35,560 (22,100)	246.80	20.34	7.10	1.83	378	113	506	5.84	1.41

Oil Additions

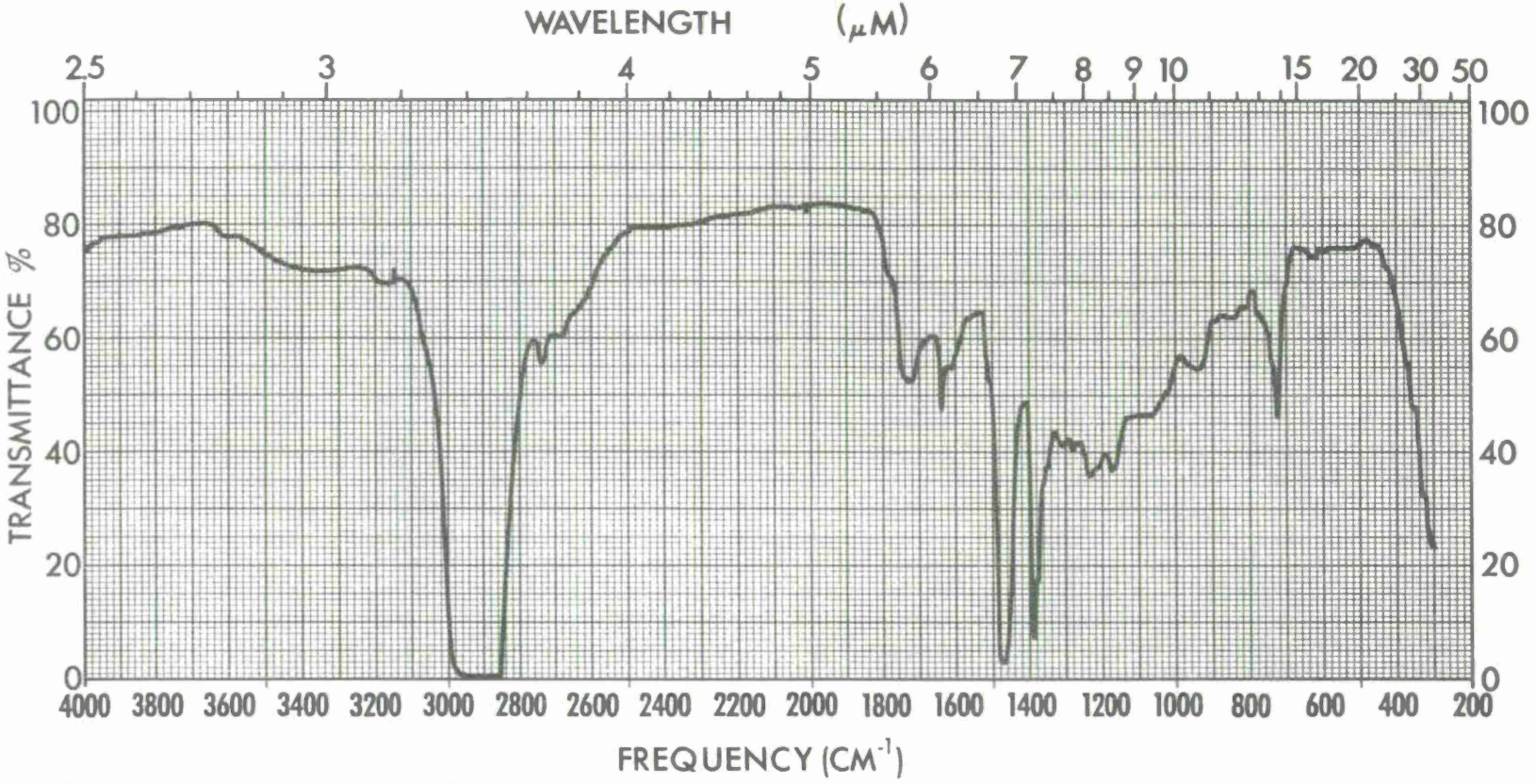
Test Distance Kilometers (miles)	Oil Addition Kilograms (lbs)	
4,988 (3100.3)	-0.03	(-0.06)
6,218 (3864.4)	0.78	(1.71)
9,294 (5776.5)	-0.02	(-0.05)
14,607 (9078.6)	-0.03	(-0.06)
16,431 (10,212.2)	0.61	(1.35)
19,717 (12,254.2)	-0.08	(-0.18)
23,741 (14,755.2)	-0.02	(-0.05)
23,741 (14,755.2)	0.60	(1.31)
29,272 (18,192.7)	-0.02	(-0.05)
29,272 (18,192.7)	0.49	(1.07)
33,608 (20,887.2)	-0.07	(-0.15)
Total Additions	2.20	(4.84)

initial oil fill - 8.43 lbs
final oil drain - 6.74 lbs
change in filter weight - 0.42 lbs



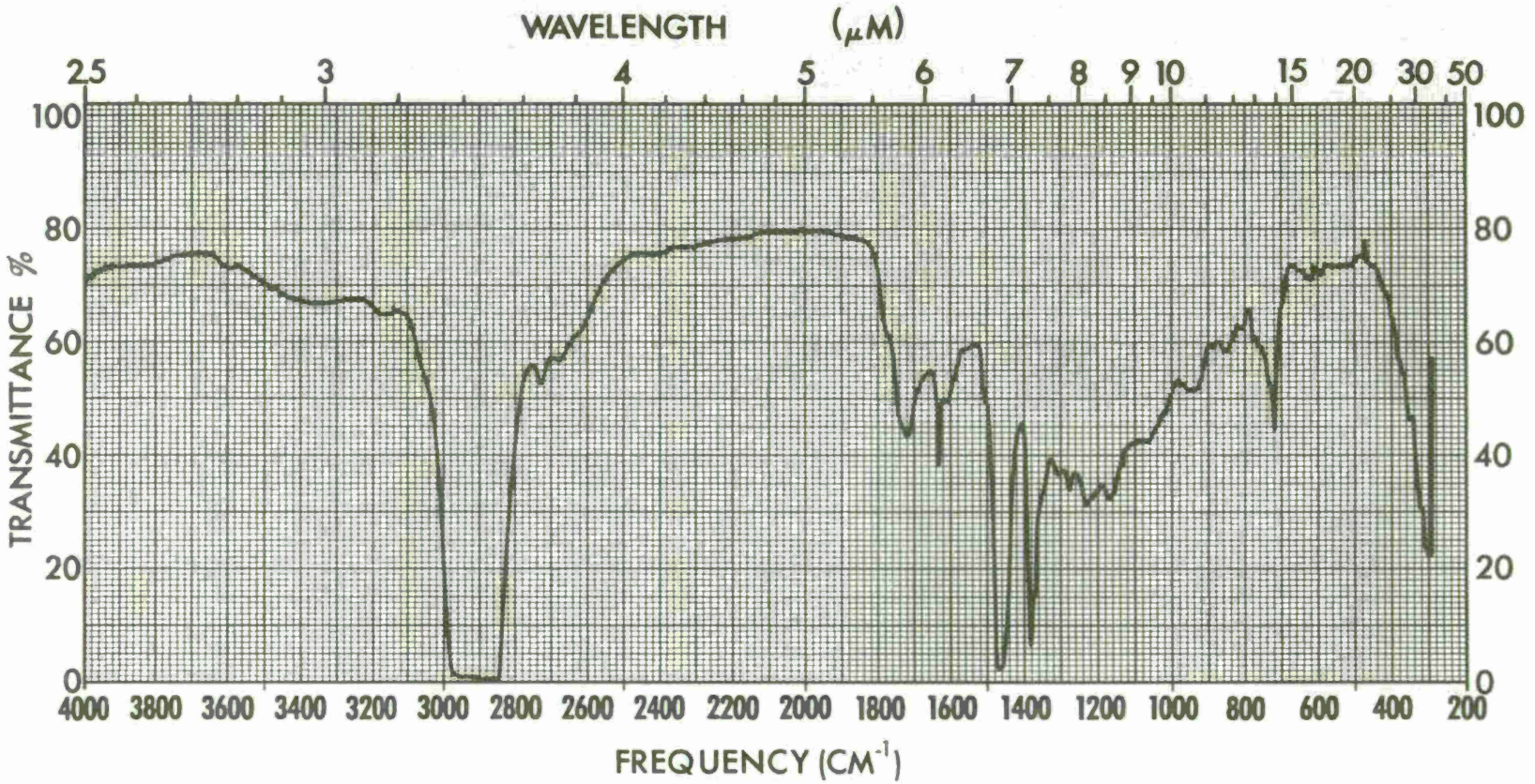
SPECTRUM NO. 569	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
NEW	PURITY	2.	
	PHASE	DATE 12-16-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. SAMPLE



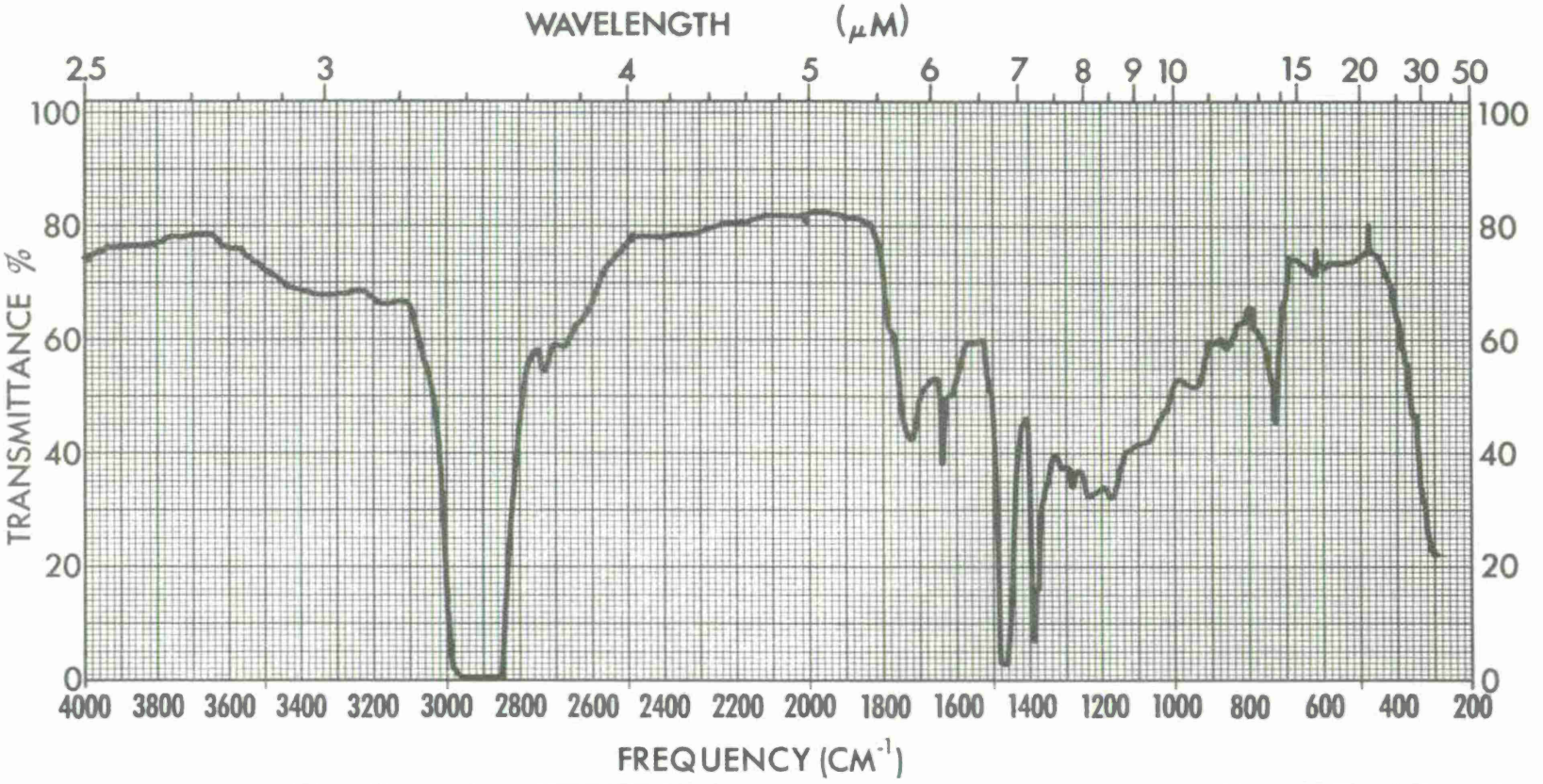
SPECTRUM NO. 661	ORIGIN	LEGEND	REMARKS
SAMPLE Standard Rings		1.	
5-21-75	PURITY	2.	
12,254.2 Miles	PHASE	DATE 5-30-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



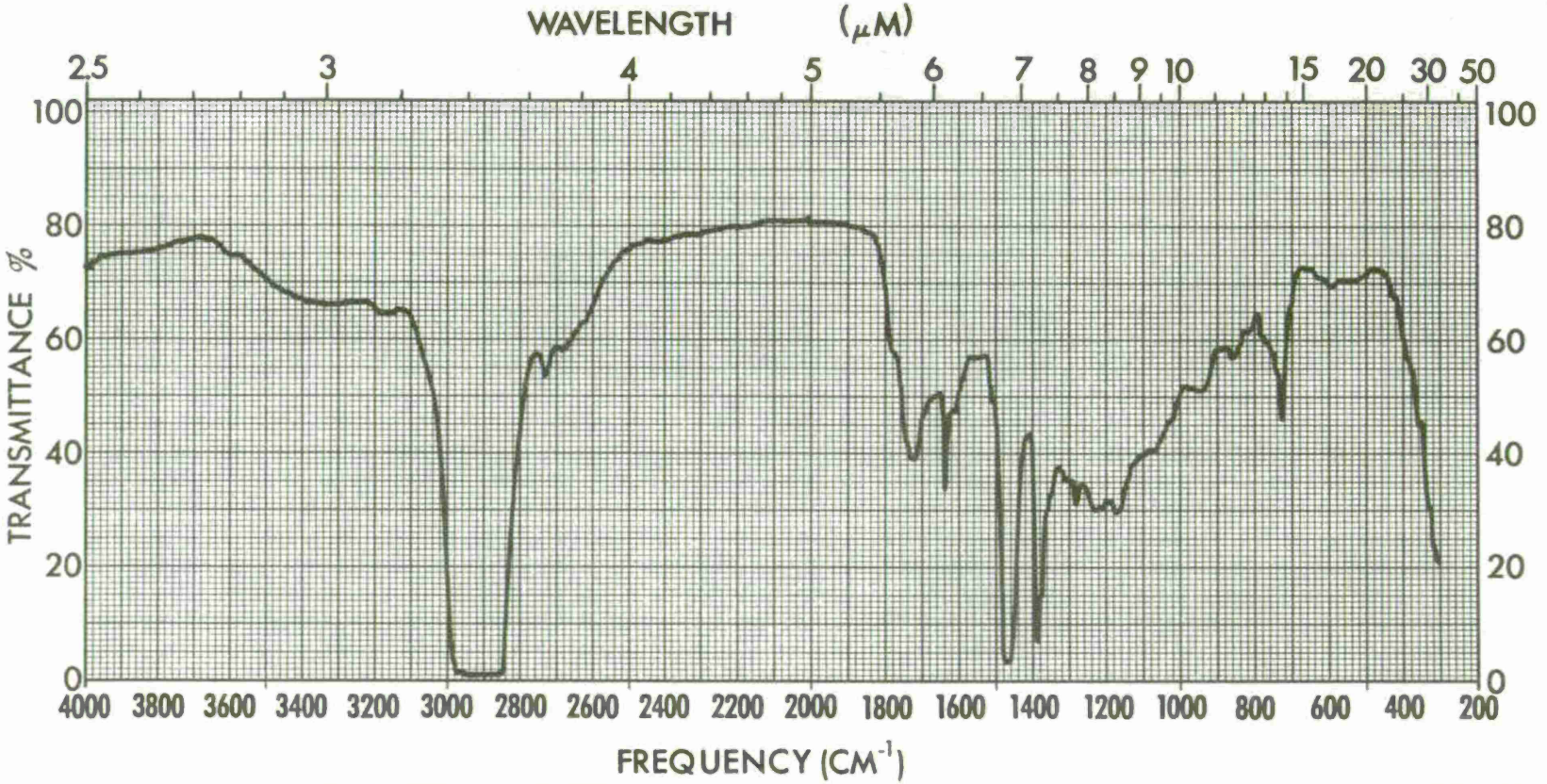
SPECTRUM NO. 665	ORIGIN	LEGEND	REMARKS
SAMPLE Standard Rings		1.	
6-4-75	PURITY	2.	
14,755 miles	PHASE	DATE 6-6-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



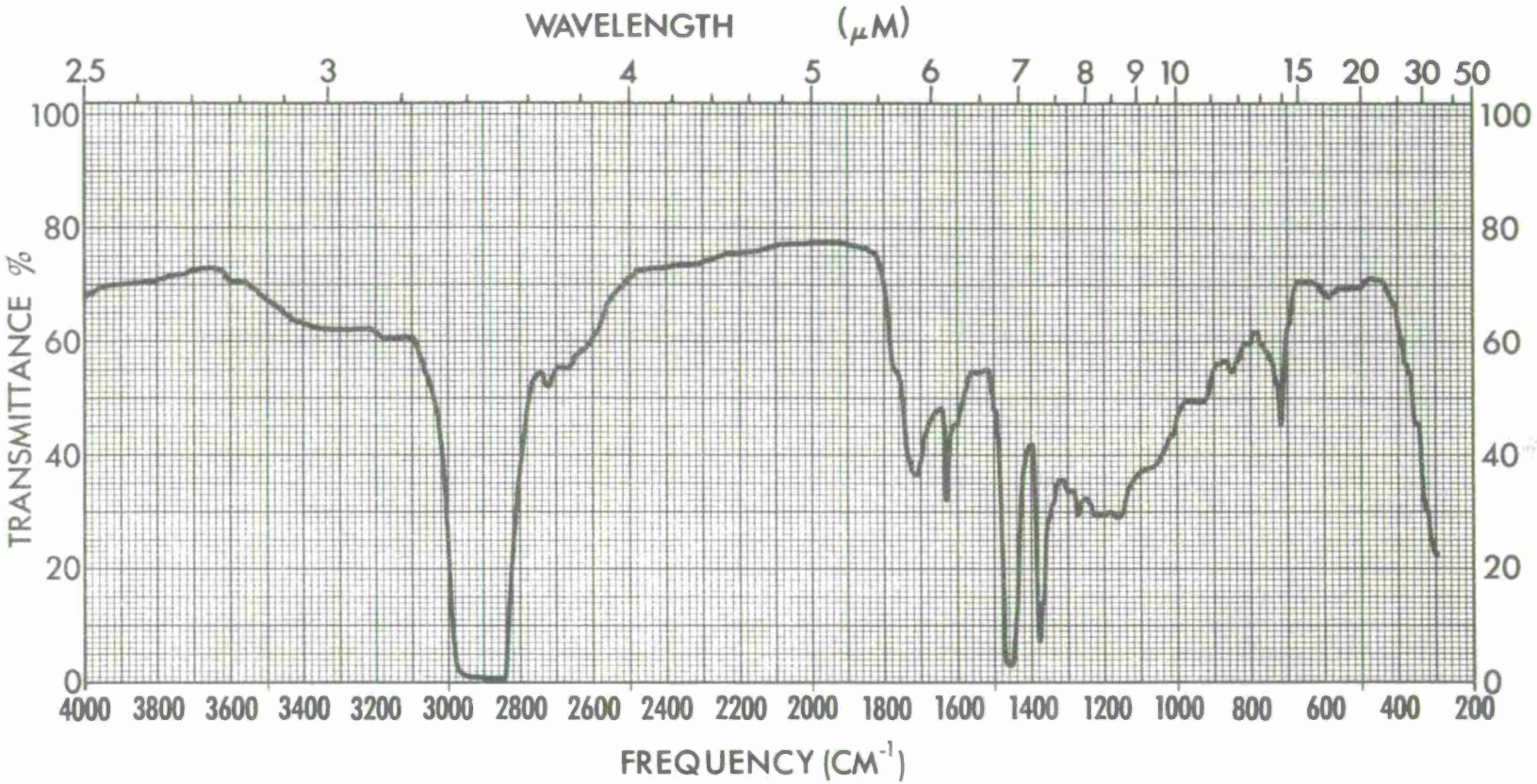
SPECTRUM NO. 671	ORIGIN	LEGEND	REMARKS
SAMPLE Standard Rings		1.	
18,192.7 Miles	PURITY	2.	
6-16-75	PHASE	DATE 6-18-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



SPECTRUM NO. 673	ORIGIN	LEGEND	REMARKS
SAMPLE Standard Rings		1.	
21,353 Miles	PURITY	2.	
6-26-75	PHASE	DATE 7-1-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



SPECTRUM NO. 675	ORIGIN	LEGEND	REMARKS
SAMPLE Standard Rings		1.	
Final, 22,100 miles	PURITY	2.	
	PHASE	DATE 7-1-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____

35,560 Kilometer Road Test - M151 Vehicle
Standard Piston Rings

List of Unscheduled Repairs

Kilometers (miles)	Fault
5,580 (3,470)	dead battery
6,900 (4,290)	front shock absorber
14,310 (8,895)	replacement of carburetor and fuel filter
19,870 (12,350)	replaced rear universal joints
21,015 (13,060)	replaced differential due to excessive backlash and wear
24,250 (15,070)	replaced rear tire

Road Octane Determinations

Kilometers (miles)	Octane No.
0	81
12,870 (8,000)	88
25,740 (16,000)	86
35,560 (22,100)	83

M151 ROAD TEST
Standard Piston Rings

Piston Ring Gap Measurements

End Gap, centimeters (inches)

Piston Ring		Piston No. 1	2	3	4
top ring	before	.046(.018)	.041(.016)	.048(.019)	.046(.018)
	after	.069(.027)	.058(.023)	.061(.024)	.058(.023)
	change	.023(.009)	.018(.007)	.013(.005)	.013(.005)
second ring	before	.051(.020)	.048(.019)	.051(.020)	.051(.020)
	after	.071(.028)	.079(.031)	.076(.030)	.074(.029)
	change	.020(.008)	.031(.012)	.025(.010)	.023(.009)

M-151 Road Test
Standard Piston Rings

Piston and Cylinder Bore Measurements

		Piston No. 1	2	3	4
Cylinder Bore, cm (in.)					
1.11 cm from Top					
Transverse	before	9.8483 (3.8773)	9.8453 (3.8761)	9.8466 (3.8766)	9.8455 (3.8762)
	after	9.8483 (3.8773)	9.8471 (3.8768)	9.8478 (3.8771)	9.8461 (3.8764)
	change	0	0.0018 (0.0007)	0.0013 (0.0005)	0.0005 (0.0002)
Longitudinal	before	9.8463 (3.8765)	9.8455 (3.8762)	9.8461 (3.8764)	9.8443 (3.8757)
	after	9.8489 (3.8775)	9.8468 (3.8767)	9.8478 (3.8771)	9.8466 (3.8766)
	change	0.0025 (0.0010)	0.0013 (0.0005)	0.0018 (0.0007)	0.0023 (0.0009)
5.87 cm from Top					
Transverse	before	9.8483 (3.8773)	9.8450 (3.8760)	9.8463 (3.8765)	9.8455 (3.8762)
	after	9.8489 (3.8775)	9.8463 (3.8765)	9.8478 (3.8771)	9.8471 (3.8768)
	change	0.0005 (0.0002)	0.0013 (0.0005)	0.0015 (0.0006)	0.0015 (0.0006)
Longitudinal	before	9.8458 (3.8763)	9.8458 (3.8763)	9.8463 (3.8765)	9.8443 (3.8757)
	after	9.8473 (3.8769)	9.8471 (3.8768)	9.8476 (3.8770)	9.8455 (3.8762)
	change	0.0015 (0.0006)	0.0013 (0.0005)	0.0013 (0.0005)	0.0013 (0.0005)
Piston Diameter (T-AT), cm (in.)					
Bottom of oil ring	before	9.8395 (3.8738)	9.8387 (3.8735)	9.8382 (3.8733)	9.8382 (3.8733)
	after	9.8374 (3.8730)	9.8362 (3.8725)	9.8379 (3.8732)	9.8367 (3.8727)
	change	0.0020 (0.0008)	0.0025 (0.0010)	0.0003 (0.0001)	0.0015 (0.0006)
Skirt	before	9.8415 (3.8746)	9.8412 (3.8745)	9.8410 (3.8744)	9.8412 (3.8745)
	after	9.8354 (3.8722)	9.8377 (3.8731)	9.8377 (3.8724)	9.8354 (3.8722)
	change	0.0061 (0.0024)	0.0036 (0.0014)	0.0051 (0.0020)	0.0058 (0.0023)

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Road Test
TEST HOURS 22,164 miles
TEST LABORATORY
LUBRICANT REO-203

RATER EL DATE
LABORATORY TEST NUMBER
STAND NO. ENGINE NO. 5029134
FUEL AL-5894-G
F rating average - excluding groove #2 - 209.78

PISTON NO. 1

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	163.1

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1		GROOVES NO. 2		GROOVES NO. 3		GROOVES NO. 4		LANDS NO. 1		LANDS NO. 2		LANDS NO. 3		LANDS NO. 4		UNDER-CROWN	
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00	50	50							85	85								
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100																		
	DBrV	0.075	50	3.75	50	3.75							50	3.75					90	6.75
	AV	0.050			50	2.50	50	2.50												
	LAV	0.025					50	1.25					50	1.25	100	2.50				
	VLAV	0.010																	10	.10
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0	0		0		0				15	0								
ZONAL RATING			53.75		6.25		3.75				85.0		5.00		2.5				6.85	
LOCATION FACTOR																				
WEIGHTED RATING																				

*WEIGHTED TOTAL DEPOSITS 156.85 with groove 2 excluded

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Road Test
TEST HOURS 22,164 miles
TEST LABORATORY
LUBRICANT REO-203

RATER EL DATE
LABORATORY TEST NUMBER
STAND NO. ENGINE NO. 5029134
FUEL AL-5894-G

PISTON NO. 2

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	173.4

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	NO. 1 DEMERIT	NO. 2 AREA-%	NO. 2 DEMERIT	NO. 3 AREA-%	NO. 3 DEMERIT	NO. 4 AREA-%	NO. 4 DEMERIT	LANDS NO. 1 AREA-%	NO. 1 DEMERIT	NO. 2 AREA-%	NO. 2 DEMERIT	NO. 3 AREA-%	NO. 3 DEMERIT	NO. 4 AREA-%	NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00	50	50							75	75								
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100	50	5.00	25	2.50					10	1.00	85	8.50					90	9.00
	DBrV	0.075			75	5.63	100	7.50			5	.38	15	1.13	100	7.50				
	AV	0.050																		
	LAV	0.025																	10	.25
	VLAV	0.010																		
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0									10	0								
ZONAL RATING			55.0		8.13		7.50				76.38		9.63		7.50				9.25	
LOCATION FACTOR																				
WEIGHTED RATING																				

*WEIGHTED TOTAL DEPOSITS 165.26 excluding groove #2

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Road Test
TEST HOURS 22,164 miles
TEST LABORATORY
LUBRICANT REO-203

RATER EL DATE
LABORATORY TEST NUMBER
STAND NO. ENGINE NO. 5029134
FUEL AL-5894-G

PISTON NO. 3

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	267.5

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00	100	100							90	90	35	35						
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100			100	10.0							65	6.50	100	10.0			85	8.50
	DBrV	0.075					100	7.50												
	AV	0.050																		
	LAV	0.025																		
	VLAV	0.010																		
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0									10	0							15	0
ZONAL RATING			100.0		10.0		7.50				90.0		41.50		10.0				8.50	
LOCATION FACTOR																				
WEIGHTED RATING																				

*WEIGHTED TOTAL DEPOSITS 257.5 excluding groove #2

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Road Test
TEST HOURS 22,164 miles
TEST LABORATORY
LUBRICANT REO-203

RATER EL DATE
LABORATORY TEST NUMBER
STAND NO. ENGINE NO. 5029134
FUEL AL-5894-G

PISTON NO. 4

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	267.0

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00	100	100							85	85	50	50						
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100											50	5.00					95	9.50
	DBrV	0.075			100	7.50														
	AV	0.050					100	5.00							100	5.00				
	LAV	0.025																		
	VLAV	0.010																		
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0									15	0							5	0
ZONAL RATING			100.0		7.50		5.00				85.0		55.0		5.0					
LOCATION FACTOR																				
WEIGHTED RATING																				

*WEIGHTED TOTAL DEPOSITS 259.5 excluding groove #2

RING STICKING

Engine Model L-141 Serial No. 5029134 Date 7-7-75
Fuel AL-5894-G Lubricant REO-203 Observer EL

Piston Number

Ring No.	1	2	3	4		
1	F	F	F	F		
2	F	F	F	F		
3	F	F	F	F		
4						

Indicate by letter—Free or Sluggish, or by number and letter—percent Pinched (cold stuck) or percent Hot stuck

RING DEPOSITS

Engine Model L-141 Serial No. 5029134 Date 7-7-75
Fuel AL-5894-G Lubricant REO-203 Observer ERL

Cylinder Number			1		2		3		4					
			CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN				
Piston Ring	Top	1	0	25	0	10	0	15	0	10				
		2	0	75	0	90	0	15	0	90				
		3												
		4												
	ID	1	0	100	0	100	100	0	30	70				
		2	0	100	0	100	0	100	0	100				
		3												
		4												
	Bottom	1	0	10	0	10	0	20	0	0				
		2	0	20	0	40	0	50	0	50				
		3												
		4												

Areas previously rated for carbon, rate 0 for varnish

RING FACE CONDITION

Engine Model L-141 Serial No. 5029134 Date 7-7-75
Fuel AL-5894-G Lubricant REO-203 Observer ERL

	Cylinder Number					
	1	2	3	4		
First Ring	N	N	N	N		
Second Ring	N	N	N	N		
Third Ring						
Fourth Ring						
Oil Ring Slots—% Open	100	100	100	100		

N-Normal

Medium Wear

PISTON SURFACE DEPOSITS

Engine Model L-141 Serial No. 5029134 Date 7-7-75
Fuel AL-5894-G Lubricant REO-203 Observer ERL

		Piston Number					
		1	2	3	4		
Top*		3.0	2.0	2.0	2.0		
Combustion Chamber*		3.5	3.0	2.5	3.5		
Under Head*		6.5	8.0	8.5	8.5		
Skirts*	Thrust	1.5	1.5	3.5	2.0		
	Anti-Thrust	1.5	1.5	3.0	2.5		
Relief Areas*		1.0	1.5	3.5	2.5		
Lands	1	8.5	8.5	8.0	8.5		
	2	6.5	8.0	8.0	8.8		
	3	5.0	7.0	7.5	6.8		
	4						

*Carbon and Ash: Use Volume Factor
Indicate H, M, or S

PISTON RING GROOVE DEPOSITS

Engine Model L-141 Serial No. 5029134 Date 7-7-75
Fuel AL-5894-G Lubricant REO-203 Observer ERL

		Cylinder Number											
		1		2		3		4					
		CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN				
Top of Groove*	1	0	0	0	5	25	5	0	5				
	2	0	15	0	80	0	30	0	50				
	3	0	90	0	90	0	90	0	90				
	4												
Back of Groove†	1	70	30	50	50	100	0	75	25				
	2	0	100	0	100	15	85	0	100				
	3	0	100	0	100	0	100	0	100				
	4												
Bottom of Groove*	1	0	5	0	5	0	5	0	0				
	2	0	5	0	10	0	20	0	10				
	3	0	0	0	10	0	100	0	25				
	4												
Drain Holes—% Blocked													

All Hard Carbon

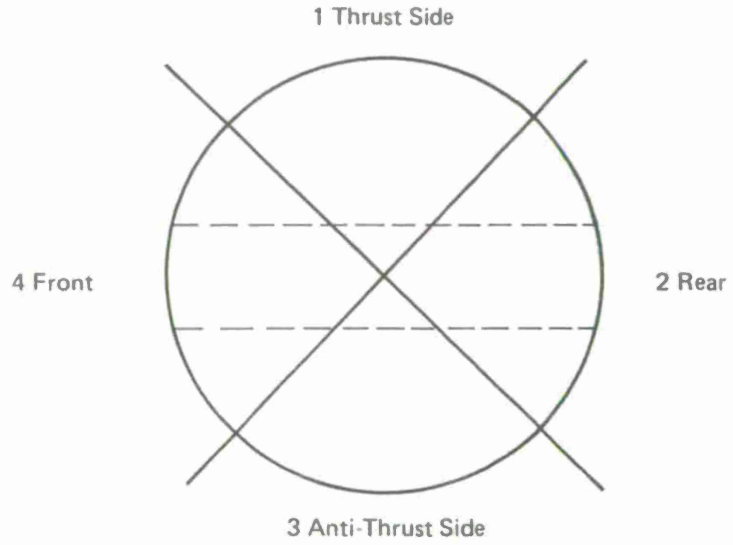
*Carbon and Ash: Use Volume Factor
Indicate H, M, or S

†Carbon and Ash: Indicate Percent Filled and H, M, or S

PISTON GROOVE INSIDE DIAMETER–% RING SUPPORTING CARBON

Engine Model L-141 Serial No. 5029134 Date 7-7-75
Fuel AL-5894-G Lubricant REO-203 Observer ERL

Piston Ring	Quadrant	Piston Number					
		1	2	3	4		
1	1	5	0	20	15		
	2	5	0	10	5		
	3	0	0	25	0		
	4	5	0	5	0		
2	1	0	0	0	0		
	2	0	0	0	0		
	3	0	0	0	0		
	4	0	0	0	0		



PISTON SURFACE CONDITION

Engine Model L-141 Serial No. 5029134 Date 7-7-75
Fuel AL-5894-G Lubricant REO-203 Observer ERL

	Piston Number					
	1	2	3	4		
Top Land	N	N	N	N		
Skirt	N	N	N	N		
Piston Pin	N	N	N	N		

N-Normal

VALVE DEPOSITS

Engine Model L-141 Serial No. 5029134 Date 7-7-75
Fuel AL-5894-G Lubricant REO-203 Observer ERL

		Cylinder Number											
		1		2		3		4					
		CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN				
Head*	INT	1.0	0	1.0	0	1.0	0	1.0	0				
	EXH	1.0	0	1.0	0	1.0	0	1.0	0				
Face	INT	0	2.0	0	4.0	0	7.5	0	9.0				
	EXH	.5	0	.5	0	.5	0	.5	0				
Tulipt	INT	6.5	0	4.5	0	3.5	0	4.0	0				
	EXH	1.5	0	1.0	0	1.0	0	1.0	0				
Stem	INT	0	0	0	0	0	0	0	0				
	EXH	0	.5	0	.5	0	.5	0	.5				

*Carbon and Ash: Use Volume Factor Technique

VALVE SURFACE CONDITIONS

Engine Model L-141 Serial No. 5029134 Date 7-7-75

Fuel AL-5894-G Lubricant REO-203 Observer EL

	Intake						Exhaust					
	1	2	3	4			1	2	3	4		
Freeness in Guide	F	F	F	F			F	F	F	F		
Head	N	N	N	N			N	N	N	N		
Face	N	N	N	N			N	N	N	N		
Seat	N	N	N	N			N	N	N	N		
Stem	N	N	N	N			N	N	N	N		
Tip	N	N	N	N			N	N	N	N		

N-Normal

F-Free

TAPPETS, CAMS, AND ROCKER ARMS

Engine Model L-141 Serial No. 5029134 Date 7-7-75
Fuel AL-5894-G Lubricant REO-203 Observer EL

			Cylinder Number					
			1	2	3	4		
Tappet Deposit		INT	0	0	0	0		
		EXH	0	0	0	0		
Tappet Surface Condition		INJ						
		INT	N	N	N	N		
		EXH	N	N	N	N		
Cam Lobes			N	N	N	N		
Rocker Arms	Tip	INT	N	N	N	N		
		EXH	N	N	N	N		
	Bushing	INT	N	N	N	N		
		EXH	N	N	N	N		
	Shaft	INT	N	N	N	N		
		EXH	N	N	N	N		

N-Normal

CYLINDERS

Engine Model L-141 Serial No. 5029134 Date 7-7-75
Fuel AL-5894-G Lubricant REO-203 Observer EL

Cylinder Number													
		1		2		3		4					
Deposits Cylinder Head		CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN				
		3.5	0	3.0	0	2.5	0	2.0	0				
Cylinders	ART	0	5.0	0	6.5	0	7.0	0	6.0				
	RTA	0	1.0	0	1.0	0	1.0	0	2.0				
	BRT	0	.5	0	.5	0	.5	0	.5				
Surface Condition													
Cylinders	RTA	N	N	N	N	N	N	N	N				
	BRTA	N	N	N	N	N	N	N	N				

SURFACE CONDITION

Engine Model L-141 Serial No. 5029134 Date 7-7-75
Fuel AL-5894-G Lubricant REO-203 Observer EL

Bearing No.	1	2	3	4			
Main–Bearing	L	N	M				
–Journal	N	N	N				
Rod–Bearing	M	M	M	M LS			
–Journal	N	N	N	N			
Piston Pin	N	N	N	N			
Bushing							

Note surface condition.

All main bearing wear on bottom half.
All cam rod bearing wear on top half.
L-light
M-Medium
L.S.-light scratch
N-Normal

SLUDGE DEPOSITS

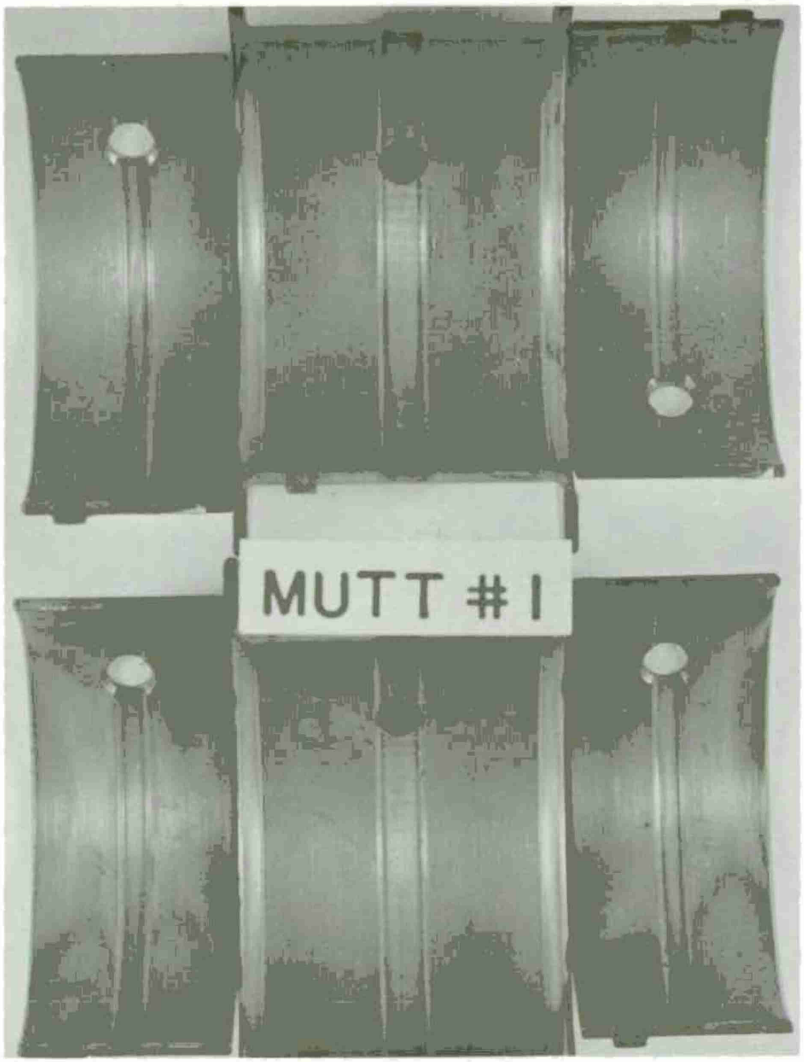
Engine Model L-141 Serial No. 5029134 Date 7-7-75
Fuel AL-5894-G Lubricant REO-203 Observer EL

	Rating
Connecting Rods	0
Rocker Arm Covers	.5
Top Deck	.5
Push Rod Covers	.5
Push Rod Chamber	.5
Timing Gear Cover	.5
Oil Pan	.5
Oil Screen	0

Use CRC Volume Factor Technique.

L-141 PISTONS, STANDARD RINGS ANTI-THRUST SIDE

L-141 PISTONS, STANDARD RINGS THRUST SIDE



STANDARD RING-EQUIPPED ENGINE
MAIN BEARINGS

STANDARD RING-EQUIPPED ENGINE
CONNECTING ROD BEARINGS

M-151 ROAD TEST RESULTS

LOW-BLOWBY PISTON RINGS

Fuel:	AL-5894-G Unleaded
Lubricant:	REO-203
Total Distance:	35,768 Kilometers (22,230 miles)
Date Completed:	27 June 1975

35,560 Kilometer Road Test - M151 Vehicle
Low Blowby Piston Rings

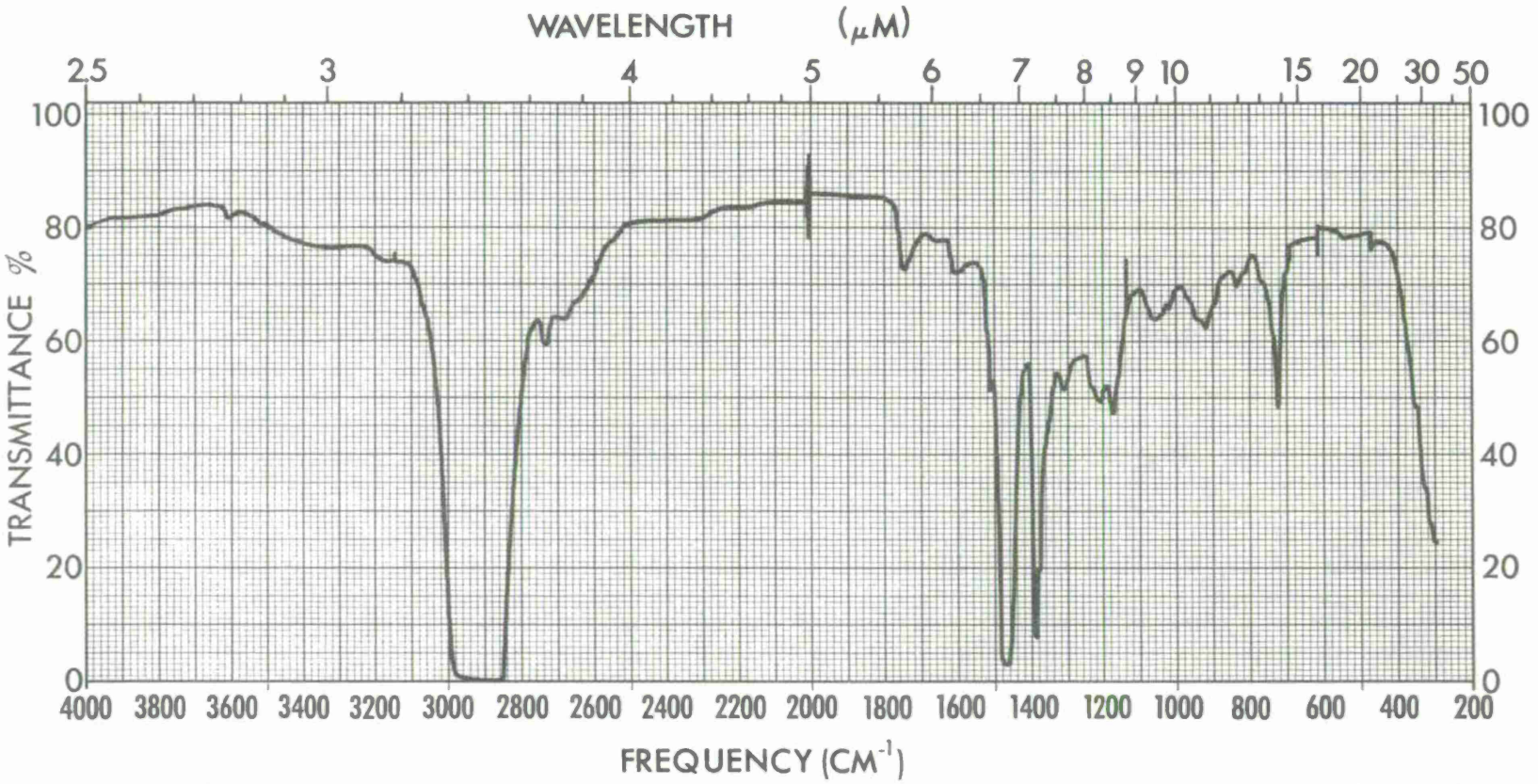
Used Oil Analysis

Test Distance Kilometers(miles)	Viscosity cS 38°C(100°F)	99°C(210°F)	TAN	TBN	Metals by AA,% Fe	Cu	Pb	Insolubles w/cong. Pentane	Benzene
New	121.6	12.61	2.97	5.08	--	--	--	--	--
(3130)	118.38	12.44	2.87	5.42	120	21	N.D.		
(5816)	123.62	12.89	3.14	4.83	169	24	N.D.		
(9111)	134.05	13.50	3.19	3.75	221	37	322		
(11,959)	146.50	14.33	4.48	3.30	262	44	420	1.03	0.45
(14,994)	148.10	14.64	4.22	4.76	321	105	478		
(18,338)	169.41	15.94	5.00	5.11	312	66	498		
(21,441)	178.61	16.81	4.69	3.19	371	73	513		
(22,100)	187.90	16.59	4.76	4.65	379	76	542	2.75	1.25

Oil Additions

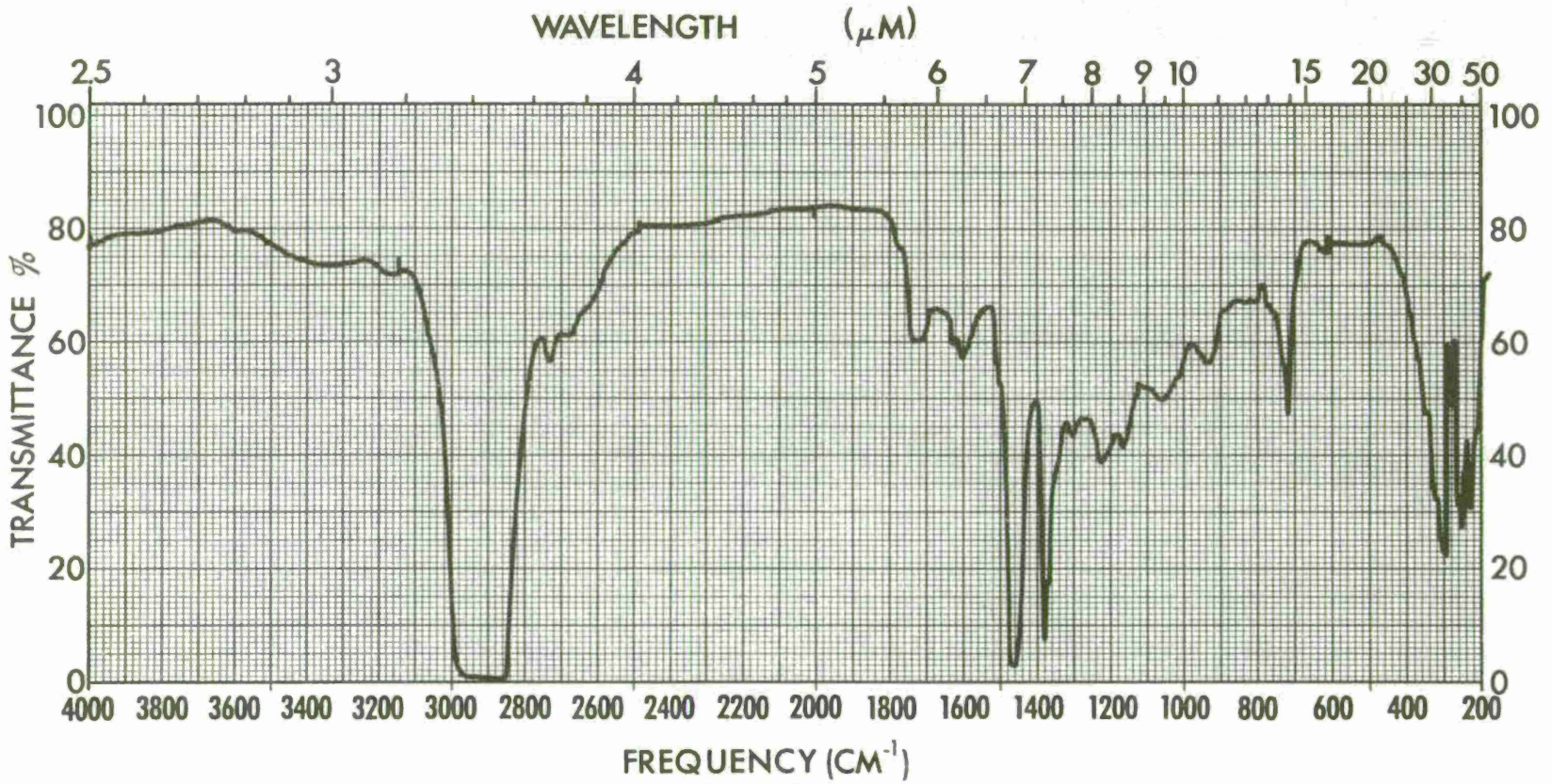
Test Distance Kilometers (miles)	Oil Addition Kilogram (lbs)	
5036 (3129)	-0.02	(-0.05)
5036 (3129)	0.95	(2.10)
9362 (5817)	-0.02	(-0.05)
14663 (9111)	-0.02	(-0.05)
19029 (11824)	-0.08	(-0.18)
19029 (11824)	0.41	(0.90)
24131 (14994)	-0.02	(-0.05)
29512 (18338)	-0.02	(-0.05)
29512 (18338)	0.32	(0.71)
33769 (20983)	-0.07	(-0.15)
Total Additions	1.42	(3.13)

initial oil fill - 3.83 Kg (8.43 lbs)
final oil drain - 2.81 Kg (6.19 lbs)
change in filter wt. - 0.29 Kg (0.64 lbs)



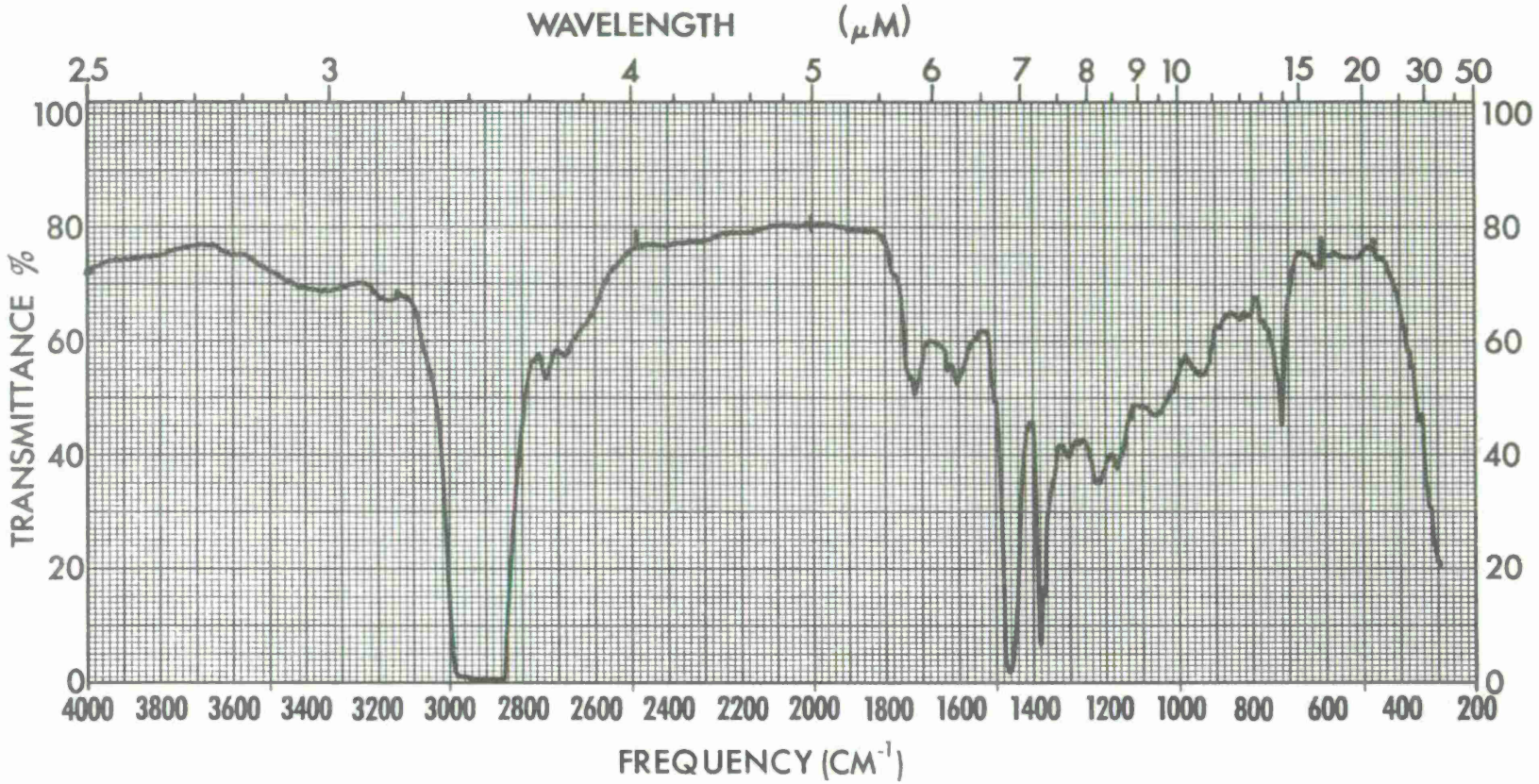
SPECTRUM NO. 569	ORIGIN	LEGEND	REMARKS
SAMPLE REO-203		1.	
NEW	PURITY	2.	
	PHASE	DATE 12-16-74	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



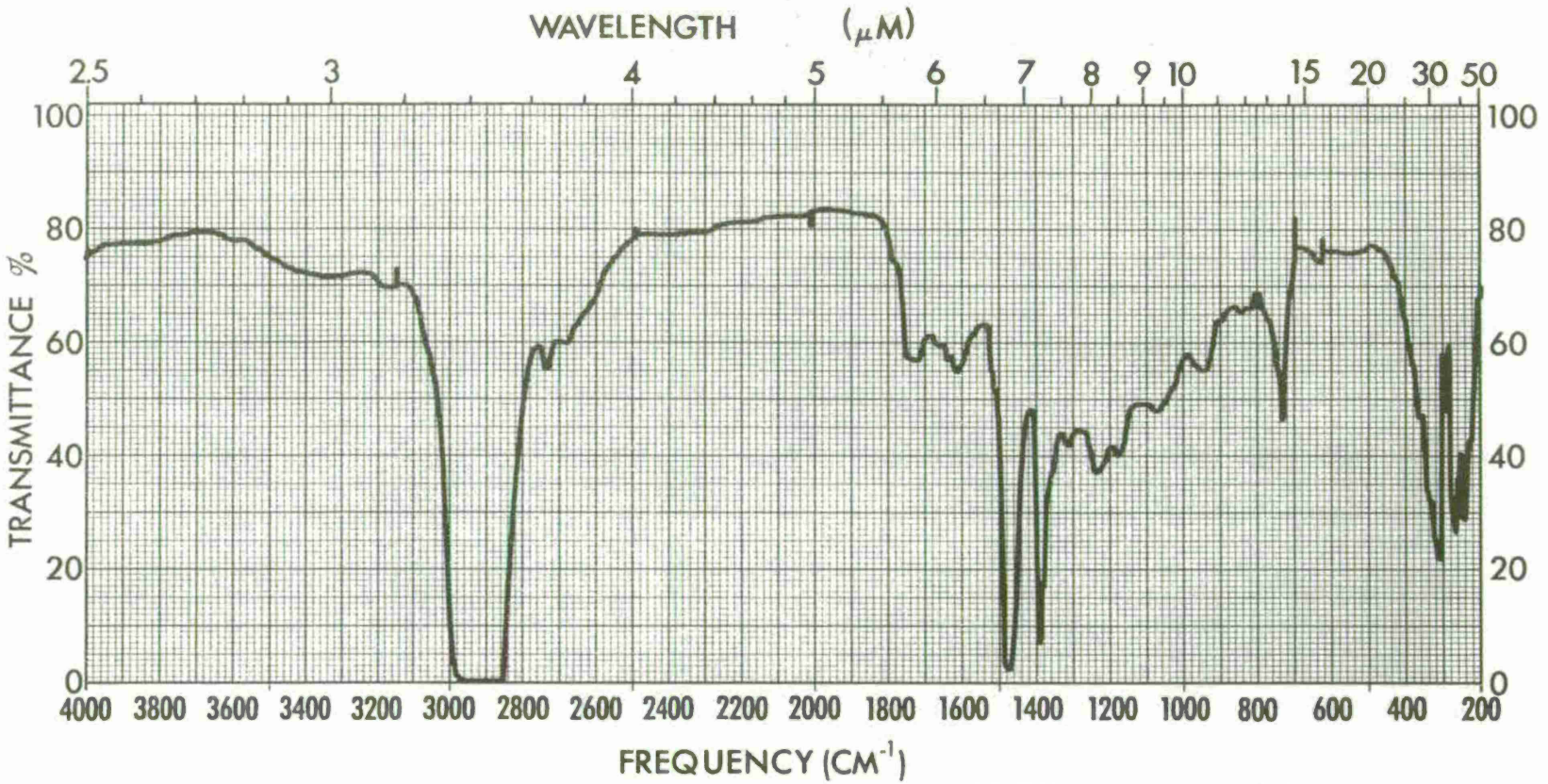
SPECTRUM NO. 662	ORIGIN	LEGEND	REMARKS
SAMPLE Low-Blowby Rings		1.	
5-21-75	PURITY	2.	
11,959.4 miles	PHASE	DATE 5-30-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



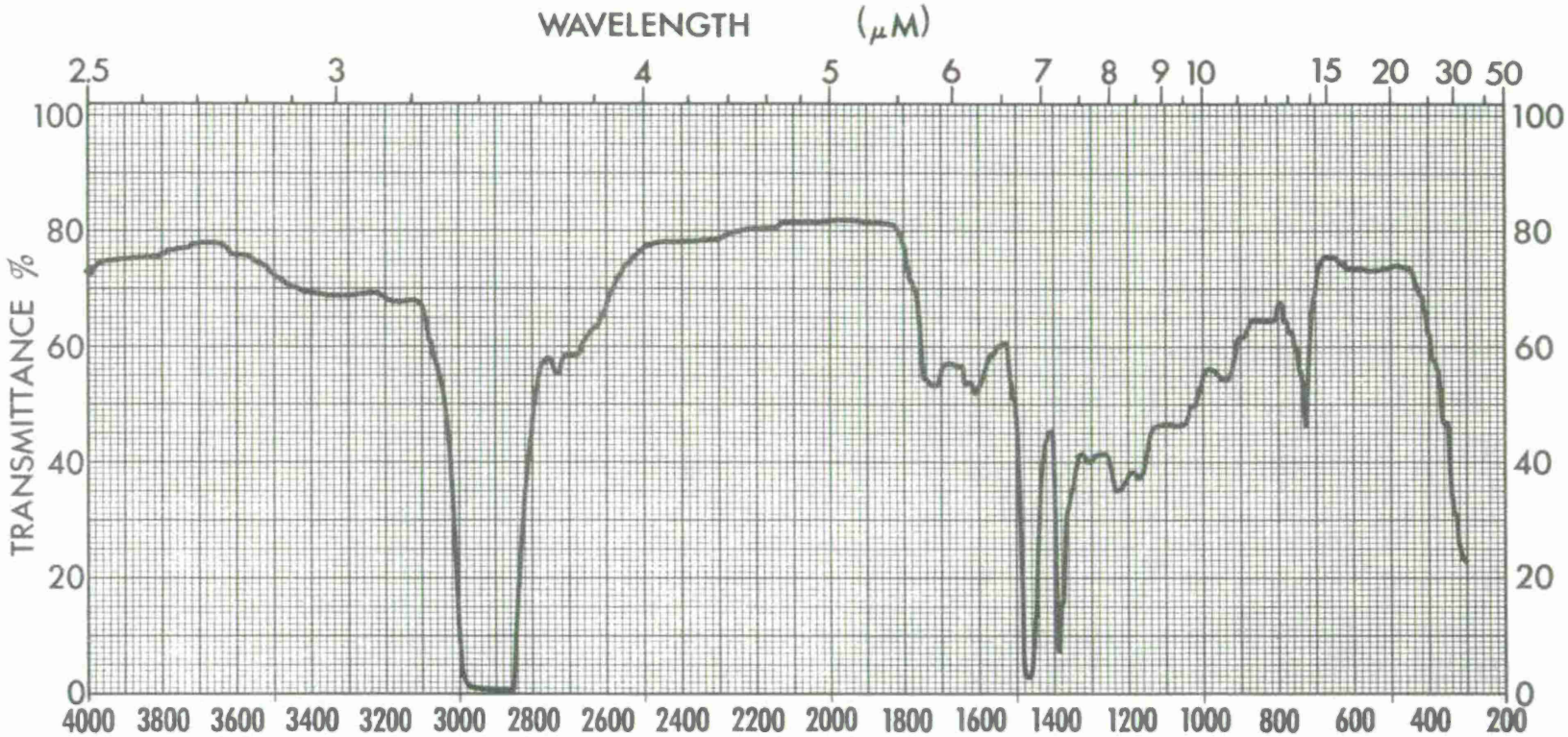
SPECTRUM NO. 666	ORIGIN	LEGEND	REMARKS
SAMPLE Low-Blowby Rings		1.	
6-4-75	PURITY	2.	
14,994 miles	PHASE	DATE 6-6-75	
	THICKNESS	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



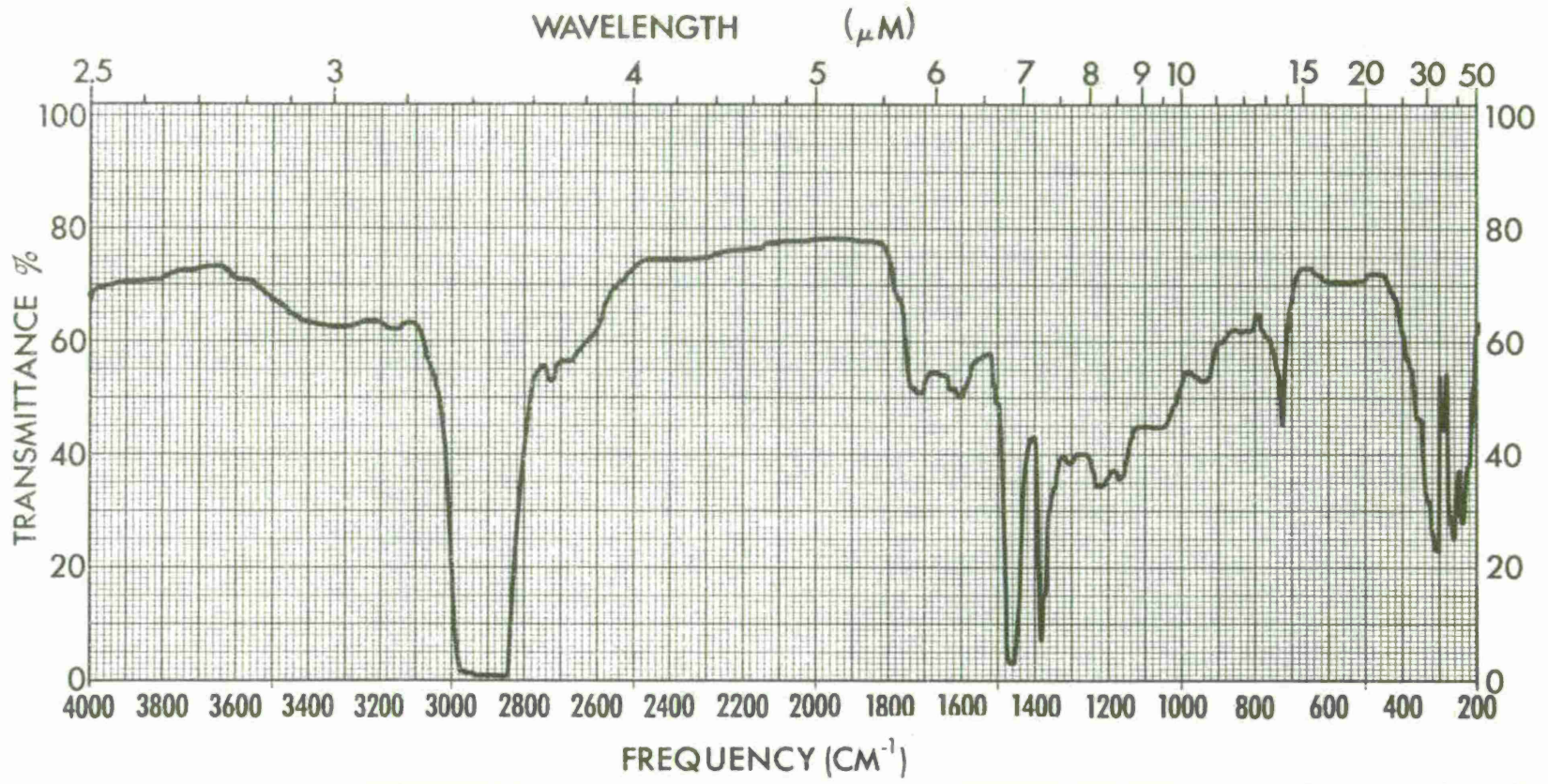
SPECTRUM NO. 672	ORIGIN	LEGEND	REMARKS
SAMPLE Low-Blowby Rings		1.	
18,338.3 miles	PURITY	2.	
6-16-75	PHASE	DATE 6-18-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



SPECTRUM NO. 674	ORIGIN	LEGEND	REMARKS
SAMPLE Low-Blowby Rings		1.	
21,441 miles	PURITY	2.	
6-26-75	PHASE	DATE 7-1-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____



SPECTRUM NO. 676	ORIGIN	LEGEND	REMARKS
SAMPLE Low-Blowby Rings		1.	
Final, 22,100 miles	PURITY	2.	
	PHASE	DATE 7-1-75	
	THICKNESS .05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____

35,560 Kilometer Road Test - M151 Vehicles
Low Blowby Piston Rings

List of Unscheduled Repairs

Kilometers (Miles)	Fault
3,070 (1,910)	cracked windshield due to vehicle upset
4,440 (2,760)	rear shock absorbers
14,365 (8,928)	replaced transmission--broken cluster gear
15,100 (9,385)	carburetor replaced
19,455 (12,090)	replaced left rear U-joint
23,460 (14,580)	repaired exhaust pipe clamp
25,070 (15,580)	replaced battery
25,520 (15,860)	replaced tire
26,935 (16,740)	replaced rear U-joints

Road Octane Determinations

Kilometers (Miles)	Octane No.
New	81
12,870 (8000)	87
25,740 (16,000)	87
35,560 (22,100)	83

M151 Road Test
Low Blowby Piston Rings

Piston Ring End Gap Measurements

centimeters (inches)

Piston Ring		Piston No. 1	2	3	4
Top Ring	before	.048(.019)	.056(.022)	.051(.020)	.056(.022)
	after	.058(.023)	.071(.028)	.066(.026)	.069(.027)
	change	.010(.004)	.015(.006)	.015(.006)	.013(.005)
Second Ring, Top	before	.033(.013)	.043(.017)	.046(.018)	.041(.016)
	after	.043(.017)	.011(.024)	.061(.024)	.051(.020)
	change	.010(.004)	.018(.007)	.015(.006)	.010(.004)
Second Ring, Bottom	before	.046(.018)	.043(.017)	.041(.016)	.038(.015)
	after	.053(.021)	.056(.022)	.058(.023)	.056(.022)
	change	.008(.003)	.013(.005)	.018(.007)	.018(.007)

M-151 Road Test
Low Blowby Piston Rings

Piston and Cylinder Bore Measurements

		Piston No. 1	2	3	4
Cylinder Bore, cm (in.)					
1.11 cm from Top					
Transverse	before	9.8478 (3.8771)	9.8471 (3.8768)	9.8471 (3.8768)	9.8463 (3.8765)
	after	9.8491 (3.8776)	9.8489 (3.8775)	9.8489 (3.8775)	9.8476 (3.8770)
	change	0.0013 (0.0005)	0.0018 (0.0007)	0.0018 (0.0007)	0.0013 (0.0005)
Longitudinal	before	9.8461 (3.8764)	9.8473 (3.8769)	9.8471 (3.8768)	9.8450 (3.8760)
	after	9.8489 (3.8775)	9.8486 (3.8774)	9.8491 (3.8776)	9.8466 (3.8766)
	change	0.0028 (0.0011)	0.0013 (0.0005)	0.0020 (0.0008)	0.0015 (0.0006)
5.87 cm from Top					
Transverse	before	9.8471 (3.8768)	9.8455 (3.8762)	9.8458 (3.8763)	9.8453 (3.8761)
	after	9.8483 (3.8773)	9.8476 (3.8770)	9.8478 (3.8771)	9.8471 (3.8768)
	change	0.0013 (0.0005)	0.0020 (0.0008)	0.0020 (0.0008)	0.0018 (0.0007)
Longitudinal	before	9.8455 (3.8762)	9.8466 (3.8766)	9.8466 (3.8766)	9.8440 (3.8756)
	after	9.8463 (3.8765)	9.8471 (3.8768)	9.8471 (3.8768)	9.8448 (3.8759)
	change	0.0008 (0.0003)	0.0005 (0.0002)	0.0005 (0.0002)	0.0008 (0.0003)
Piston Diameter (T-AT) cm (in.)					
Bottom of oil ring	before	9.8405 (3.8742)	9.8384 (3.8734)	9.8410 (3.8744)	9.8405 (3.8742)
	after	9.8379 (3.8732)	9.8364 (3.8726)	9.8367 (3.8727)	9.8369 (3.8728)
	change	0.0025 (0.0010)	0.0020 (0.0008)	0.0043 (0.0017)	0.0036 (0.0014)
Skirt	before	9.8356 (3.8723)	9.8379 (3.8732)	9.8379 (3.8732)	9.8377 (3.8731)
	after	9.8400 (3.8740)	9.8356 (3.8723)	9.8372 (3.8729)	9.8369 (3.8728)
	change	-0.0043 (-0.0017)	0.0023 (0.0009)	0.0008 (0.0003)	0.0008 (0.0003)

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Road Test
TEST HOURS 22,230 miles
TEST LABORATORY
LUBRICANT REO-203

RATER EL DATE 7-9-75
LABORATORY TEST NUMBER
STAND NO. ENGINE NO. 5029203
FUEL AL-5893-G
Average rating - groove #2 excluded - 106.9

PISTON NO. 1

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	103.26

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	NO. 1 DEMERIT	NO. 2 AREA-%	NO. 2 DEMERIT	NO. 3 AREA-%	NO. 3 DEMERIT	NO. 4 AREA-%	NO. 4 DEMERIT	LANDS NO. 1 AREA-%	NO. 1 DEMERIT	NO. 2 AREA-%	NO. 2 DEMERIT	NO. 3 AREA-%	NO. 3 DEMERIT	NO. 4 AREA-%	NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00									75	75								
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100	80	8.00									10	1.0						
	DBrV	0.075	20	1.50									20	1.50	50	3.75				
	AV	0.050					50	2.50					30	1.50	50	2.50			50	2.50
	LAV	0.025					50	1.25					40	1.00					50	1.25
	VLAV	0.010																		
	RV	0.001									10	.01								
	VARNISH RATING																			
CLEAN		0									15	0								
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING			9.5		N.R.		3.75				75.01		5.00		6.25					

*WEIGHTED TOTAL DEPOSITS

N.R. - not rated

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Road Test
TEST HOURS 22,230 miles
TEST LABORATORY
LUBRICANT REO-203

RATER EL DATE 7-9-75
LABORATORY TEST NUMBER
STAND NO. ENGINE NO. 5029203
FUEL AL-5893-G

PISTON NO. 2

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	115.75

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00									75	75.0								
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100	100	10.0									80	8.00						
	DBrV	0.075					100	7.50					20	1.50	100	7.50			50	3.75
	AV	0.050																		2.50
	LAV	0.025																		
	VLAV	0.010																		
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0									25*	0								
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING			10.0		N.R.		7.50				75.0		9.50		7.50				6.25	

*WEIGHTED TOTAL DEPOSITS

*rubbed clean by contact with cylinder wall.

N.R. - not rated

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Road Test
TEST HOURS 22,230 miles
TEST LABORATORY
LUBRICANT REO-203

RATER EL DATE 7-9-75
LABORATORY TEST NUMBER
STAND NO. ENGINE NO. 5029203
FUEL AL-5893-G

PISTON NO. 3

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	102.38

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON HC	1.00									60	60.0								
CARBON MHC	0.75																		
CARBON MC	0.50																		
CARBON LC	0.25																		
CARBON VLC	0.15																		
CARBON RATING																			
VARNISH BV	0.100	100	10.0									100	10.0						
VARNISH DBrV	0.075					100	7.50			5	0.38			100	7.50			80	6.00
VARNISH AV	0.050																	20	1.00
VARNISH LAV	0.025																		
VARNISH VLAV	0.010																		
VARNISH RV	0.001																		
VARNISH RATING																			
CLEAN	0									35+	0								
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING		10.0		N.R.		7.50				60.38		10.0		7.50				7.0	

*WEIGHTED TOTAL DEPOSITS

+ rubbed clean by contact with cylinder wall

N.R. - not rated

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE Road Test
TEST HOURS 22,230 miles
TEST LABORATORY
LUBRICANT REO-203

RATER EL DATE 7-9-75
LABORATORY TEST NUMBER
STAND NO. ENGINE NO. 5029203
FUEL AL-5993-G

PISTON NO. 4

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	106.4

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00									70	70.0								
	MHC	0.75																		
	MC	0.50																		
	LC	0.25																		
	VLC	0.15																		
	CARBON RATING																			
VARNISH	BV	0.100	100	10.0									50	5.00						
	DBrV	0.075									5	.38	50	3.75	70	5.25			80	6.00
	AV	0.050					50	2.50							30	1.50			10	.50
	LAV	0.025					50	1.25											10	.25
	VLAV	0.010																		
	RV	0.001																		
	VARNISH RATING																			
CLEAN		0									20+	0								
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING			10.0		N.R.		3.75				70.38		8.75		6.75				6.75	

*WEIGHTED TOTAL DEPOSITS

+ wiped clean from contact with cylinder wall

N.R. - not rated

RING STICKING

Engine Model L-141 "low blowby" Serial No. 5029203 Date 7-9-75
Fuel AL-5893-G Lubricant REO-203 Observer EL.

Piston Number

Ring No.	1	2	3	4		
1	F	F	F	F		
2	F	F	F	F		
3	F	F	F	F		
4						

Indicate by letter– Free or Sluggish, or by number and letter–percent Pinched (cold stuck) or percent Hot stuck

RING FACE CONDITION

Engine Model L-141 "low blowby" Serial No. 5029203 Date 7-9-75
Fuel AL-5893-G Lubricant REO-203 Observer EL

	Cylinder Number					
	1	2	3	4		
First Ring	N	N	N	N		
Second Ring	N	N	N	N		
Third Ring	N	N	N	N		
Fourth Ring						
Oil Ring Slots—% Open	100	100	100	100		

N-Normal

PISTON SURFACE DEPOSITS

Engine Model L-141 "Low Blowby" Serial No. 5029203 Date 7-9-75
Fuel AL-5893-G Lubricant REO-203 Observer EL

		Piston Number					
		1	2	3	4		
Top*		3.0	3.0	3.0	3.0		
Combustion Chamber*		4.0	4.0	4.0	4.0		
Under Head*		3.75	6.35	7.0	6.75		
Skirts*	Thrust	1.0	.75	.5	.5		
	Anti-Thrust	.5	.5	.5	.5		
Relief Areas*		1.0	.75	.5	.5		
Lands	1	7.5	7.5	6.75	7.38		
	2	4.8	9.5	10.0	8.75		
	3	6.25	7.5	7.50	6.75		
	4						

*Carbon and Ash: Use Volume Factor
Indicate H, M, or S

PISTON RING GROOVE DEPOSITS

Engine Model L-141 "Low Blowby" Serial No. 5029203 Date 7-9-75
Fuel AL-5893-G Lubricant REO-203 Observer EL

		Cylinder Number											
		1		2		3		4					
		CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN				
Top of Groove*	1	0	0	0	0	0	0	0	0				
	2	0	0	0	0	0	0	0	0				
	3	0	90	0	90	0	40	0	90				
	4												
Back of Groove†	1	0	100	0	100	0	100	0	100				
	2	0	100	0	100	0	100	0	100				
	3	0	100	0	100	0	100	0	100				
	4												
Bottom of Groove*	1	0	0	0	0	0	0	0	0				
	2	0	0	0	0	0	0	0	0				
	3	0	10	0	10	0	10	0	10				
	4												
Drain Holes—% Blocked		0	0	0	0	0	0	0	0				

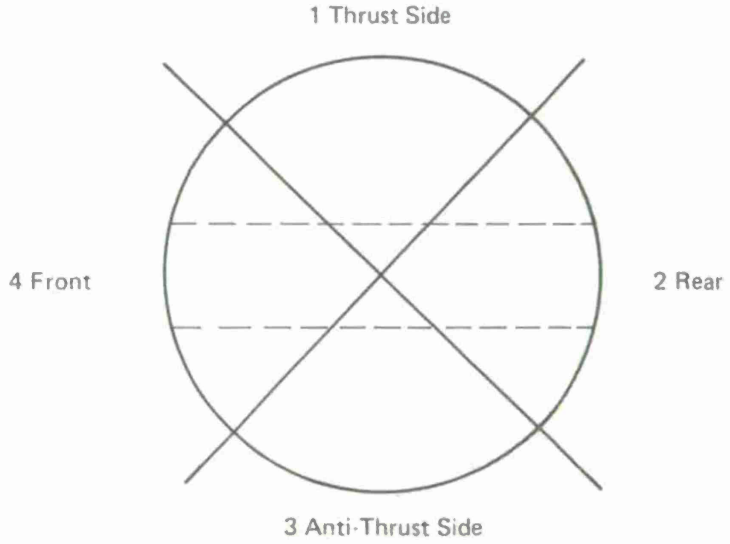
*Carbon and Ash: Use Volume Factor
Indicate H, M, or S

†Carbon and Ash: Indicate Percent Filled and H, M, or S

PISTON GROOVE INSIDE DIAMETER–% RING SUPPORTING CARBON

Engine Model L-141 "Low Blowby" Serial No. 5029203 Date 7-9-75
Fuel AL-5893-G Lubricant REO-203 Observer EL

Piston Ring	Quadrant	Piston Number					
		1	2	3	4		
1	1	0	0	0	0		
	2	0	0	0	0		
	3	0	0	0	0		
	4	0	0	0	0		
2	1	0	0	0	0		
	2	0	0	0	0		
	3	0	0	0	0		
	4	0	0	0	0		



PISTON SURFACE CONDITION

Engine Model L-141 "Low Blowby" Serial No. 5029203 Date 7-9-75
Fuel AL-5893-G Lubricant REO-203 Observer EL

	Piston Number					
	1	2	3	4		
Top Land	X	X	X	X		
Skirt	N	N	N	N		
Piston Pin	N	N	N	N		

X-All top lands wiped clean on anti thrust side.

N-Normal

VALVE DEPOSITS

Engine Model L-141 "Low Blowby" Serial No. 5029203 Date 7-9-75
Fuel AL-5893-G Lubricant REO-203 Observer EL

		Cylinder Number											
		1		2		3		4					
		CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN				
Head*	INT	1.0	0	1.5	0	1.0	0	1.0	0				
	EXH	1.5	0	1.5	0	1.5	0	1.0	0				
Face	INT	0	5.0	0	6.0	0	5.0	0	5.0				
	EXH	1.0	0	1.0	0	1.0	0	1.0	0				
Tulipt	INT	4.8	0	3.5	0	4.0	0	4.0	0				
	EXH	1.0	0	1.0	0	1.0	0	1.0	0				
Stem	INT	0	0	0	0	0	0	0	0				
	EXH	0	1.5	0	1.0	0	1.0	1.0	0				

*Carbon and Ash: Use Volume Factor Technique

VALVE SURFACE CONDITIONS

Engine Model L-141 "Low Blowby" Serial No. 5029203 Date 7-9-75
Fuel A1-5893-G Lubricant REO-203 Observer EL

	Intake						Exhaust					
	1	2	3	4			1	2	3	4		
Freeness in Guide	F	F	F	F			F	F	F	F		
Head	N	N	N	N			N	N	N	N		
Face	N	N	N	N			N	N	N	N		
Seat	N	N	N	N			N	N	N	N		
Stem	N	N	N	N			N	N	N	N		
Tip	N	N	N	N			N	N	N	N		

N - normal

F- Free

TAPPETS, CAMS, AND ROCKER ARMS

Engine Model L-141 "Low Blowby Serial No. 5029203 Date 7-9-75
Fuel AL-5893-G Lubricant REO=203 Observer EL

			Cylinder Number					
			1	2	3	4		
Tappet Deposit		INT	0	0	0	0		
		EXH	0	0	0	0		
Tappet Surface Condition		INJ						
		INT	N	N	N	N		
		EXH	N	N	N	N		
Cam Lobes			N	N	N	N		
Rocker Arms	Tip	INT	N	N	N	N		
		EXH	N	N	N	N		
	Bushing	INT	N	N	N	N		
		EXH	N	N	N	N		
	Shaft	INT	N	N	N	N		
		EXH	N	N	N	N		

N - normal

CYLINDERS

Engine Model L-141 "low blowby" Serial No. 5029203 Date 7-9-75
Fuel AL-5893-G Lubricant REO-203 Observer EL

Cylinder Number														
		1		2		3		4						
Deposits Cylinder Head		CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN					
		4.0	0	4.0	0	4.0	0	4.0	0					
Cylinders	ART	0	5.0	0	5.0	0	4.0	0	4.0					
	RTA	0	0	0	0	0	0	0	0					
	BRT	0	0	0	0	0	0	0	0					
Surface Condition		N	N	N	N	N	N	N	N					
Cylinders	RTA	N	N	N	N	N	N	N	N					
	BRTA	N	N	N	N	N	N	N	N					

Carbon and Ash: Use Volume Factor
Indicate H, M, or S

SURFACE CONDITION

Engine Model L-141 "Low Blowby" Serial No. 5029203 Date 7-9-75
Fuel A1-5893-G Lubricant REO-203 Observer EL

Bearing No.	1	2	3	4			
Main—Bearing	MW	LW	MW				
—Journal	N	N	N				
Rod—Bearing	LW	LW	LMW	LMW			
—Journal	N	N	N	N			
Piston Pin	N	N	N	N			
Bushing	N	N	N	N			

Note surface condition.

L - light
W - wear
M - medium
N - Normal

All wear on main bearing on bottom except LW top #1.

All wear on con rod bearing on top exctp #1 has LW on bottom.

SLUDGE DEPOSITS

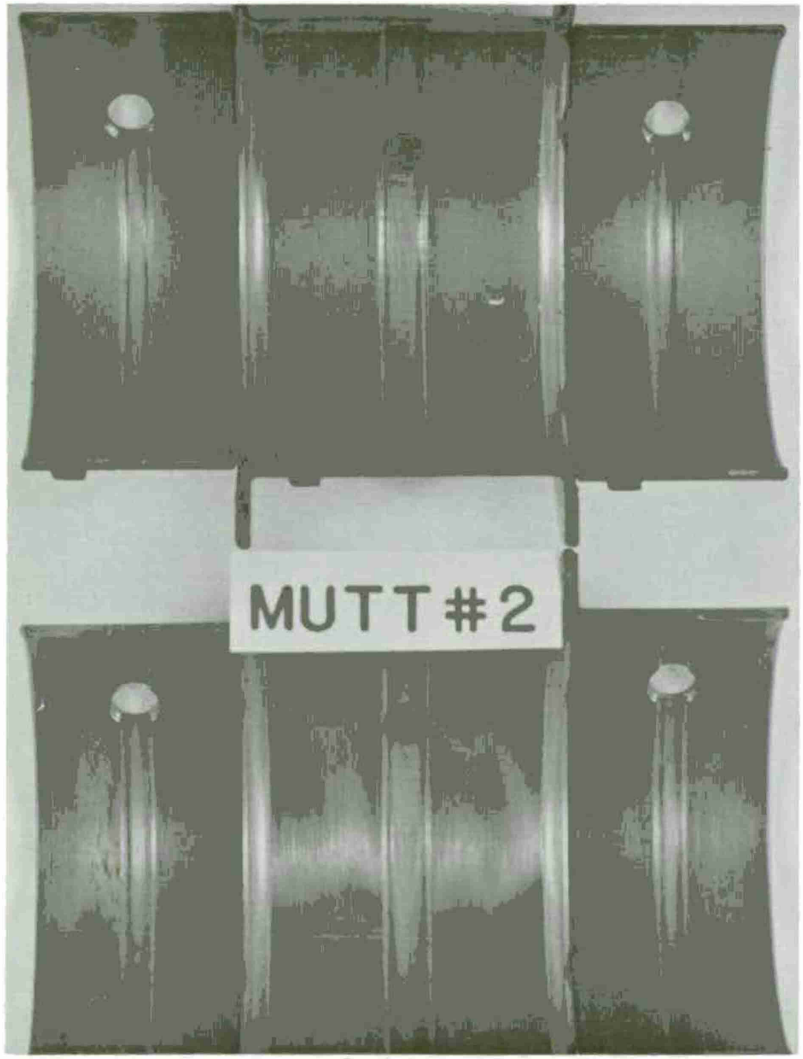
Engine Model L-141 "Low Blowby" Serial No. 5029203 Date 7-9-75
Fuel AL-5893-G Lubricant REO-203 Observer EL

	Rating
Connecting Rods	.5
Rocker Arm Covers	.5
Top Deck	.5
Push Rod Covers	.5
Push Rod Chamber	.5
Timing Gear Cover	.5
Oil Pan	.5
Oil Screen	0

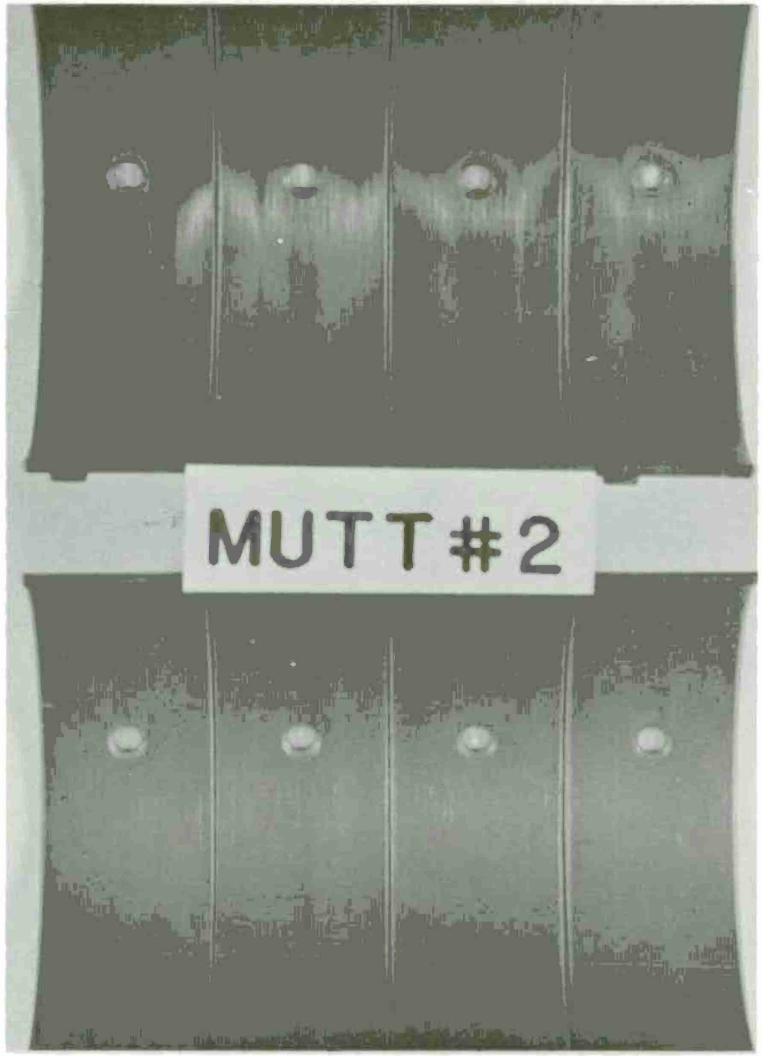
Use CRC Volume Factor Technique.

L-141 ENGINE, LOW-BLOWBY RINGS ANTI-THRUST SIDE

L-141 ENGINE, LOW-BLOWBY RINGS THRUST SIDE



LOW-BLOWBY RING-EQUIPPED ENGINE
MAIN BEARINGS



LOW-BLOWBY RING-EQUIPPED ENGINE
CONNECTING ROD BEARINGS

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